A Dynamic Model of Growth and Decline in Industrial Cities

by

Vasilis Angelis

A thesis submitted to the University of Warwick for the degree of Ph.D. December 1978.

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VOLUME A

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Summary

The principal aim of this study is the construction of a dynamic model for the analysis of the process of development – growth or decline – of an industrial city.

The study is divided into four parts:

Part 1 discusses the Dynamics of the industrial city and introduces one of the funoamental concepts for the construction of the model; the Image of the city. It is argued that the Image of a city displays generally discontinuous behaviour and Catastrophe Theory is used for its study.

Part 2 covers the presentation of the model. It is divided into five submodels and behavioural relations are used in a simulation context to represent the interactions between the various urban entities. Although the proposed model is primarily descriptive, extensions of its use for planning purposes are also discussed.

Part 3 concentrates on the testing of the model. Data for Coventry and Oldham is used, both to validate the use of the concept of a city's Image in modelling urban development and then to test the descriptive power of a particular model using that concept. The results obtained by running the model program for Coventry and Oldham but also for a number of other cities show a satisfactory fit to historical reality.

Finally, Part 4 consists of several Appendices containing technical and statistical details.

For easier presentation, the contents of the study have been arranged into two volumes A and B containing Parts 1-3 and Part 4 respectively.

Introduction

Almost eighty years ago Adna Weber[1], referring to Western Europe and North America, was writing that "the most remarkable social phenomenon of the present century is the concentration of population in cities". The very same phrase could be used today for the so-called Third-World countries.

Rapid urbanisation is a phenomenon that started more than 150 years ago in a certain part of the world and still goes on today,on an even greater scale,in a different part. Industrial urbanisation firstly took place in Britain and neighbouring North-Western Europe and then in North America. As early as 1843 Britain was already "in the age of great cities" according to Robert Vaughan[2]. From 1801 to 1911 Britain's urban areas accounted for 94% of the country's population increase and North America experienced a similar trend. During the 20th century, however, an urbanisation process, as fast and profound as that of Europe and North America, has been experienced in the countries of the Third-World. During the last 50 years the Third-World countries have had an almost seven-fold increase of their urban population as compared to an only three-fold increase of the urban population of the developed countries. The big-

-city population of the Third-World increased even faster -nine-fold- during the period 1920-60 as compared to 0.6 times for Europe (Berry[3]). As a result of this almost continuous process, a high and ever increasing percentage of the earth's population live in cities.

To understand the city and its life we need to see the city as more than a mere spot on a map. Cities are places of different size and physical structure; alternatively, they are sets of people belonging to different racial, religious and socio-economic groups tied together by certain common interests and behaving in a way which reflects the principles of urban living. Although the way of life tends to be similar in all cities of the world, cities do differ and various classifications have been proposed based on some common feature or other. Prof. P.Geddes[4], for example, has suggested that cities may be classified according to their social functions as follows:

(i) Primary cities, that serve production (i.e.mining or manufacturing towns).

(ii) Secondary cities, that serve distribution (i.e. marketing, warehousing, importing and exporting).

(iii) Tertiary cities, that provide residential, recreational and educational facilities (i.e. University cities, sea-resorts).

This classification is as good as any; its main disadvantage lies in the fact that a city is very rarely of a pure type. In spite of its shortcomings I have referred to this classification in order to stress that the main objective of this work is the construction of a model for cities that are closest to the first of the above mentioned groups. I shall be referring to such cities as Industrial Cities. "City" is one of those words that can be used in several distinct but related senses; moreover the boundaries of a city although legally and politically fixed are economically and socially vague. The model I am going to introduce has been constructed to describe cities where the majority of economically active persons work and live within the politically fixed boundaries. However it may also be used – with slight modifications only – to describe cities functioning within a wider commuter region. The modifications will be discussed in due course.

The thesis consists of two volumes and is divided into four parts. Volume A contains Parts 1-3 while Volume B contains Part 4.

Part 1, which is introductory, consists of Chapters 1-3. Chapter 1 presents a brief history of the forms of human settlements and their transformations through the years, Special emphasis is placed on the analysis of the forces which led to the emergence of the first industrial cities. Chapter 2 introduces the notion of mathematical models and model building, firstly in general and then in connection with urban problems. A review of selected urban models is also included in this chapter. Finally, Chapter 3, presents a theoretical analysis of the process of the development of an industrial city and introduces two concepts of central importance for the proposed model: the concepts of Basic and Specific Image of a city. It is argued that the Basic Image of a city – represented as a function of two indicators, an Industrial and a Social – displays generally discontinuous behaviour. Catastrophe Theory is employed for its study.

Part 2 consists of Chapters 4-10 and is devoted to the presentation of the proposed model which has been divided into five submodels. Chapter 4 gives a brief outline of both the conceptual and the technical structure of the model while the next five chapters present its five submodels in turn. Chapter 5 analyses and models the process of change in the coefficients ot the equation expressing the Basic Image of a city. Chapter 6 models the derivation of the

Basic Image of a given city while Chapter 7 models the derivation of its Specific Image as perceived by the various groups of potential movers. Chapter 8 analyses the process of change in the stocks of the various urban entities during each time period. Chapter 9 is devoted to the analysis of spatial distribution of the various urban entities over the city area. Guidelines for an eventual modelling of this process are also given. The proposed model is primarily a descriptive one. Chapter 10, however, explores its potential uses for predictive and planning purposes. A special reference is made to the potential use of this model as tool for urban planning in Third-World countries.

Part 3, consisting of Chapters 11 and 12, describes the testing of the proposed model. Chapter 11 uses data from Coventry and Oldham to justify the use of the concept of Basic Image for modelling urban development. Chapter 12 uses data from the same cities to test the descriptive power of the model.

Part 4 consists of six technical and statistical Appendices. Appendix 1 contains a brief introduction to Catastrophe Theory. Thom's classification theorem is presented and its interpretations are discussed. Special emphasis is, however, placed on the presentation of the Cusp Catastrophe Model which has been used for the analysis of the concept of a city's Basic Image. Appendix 2 describes the derivation of the values for the various exogenous variables used in the model. Appendix 3 lists in alphabetical order all the terms used in each sector of the constructed model together with their definitions. Appendix 4 lists the version of the model used to simulate the development of a hypothetical city - representing the average English city - over the period 1800-1970. The computed characteristics of this city serve, among other variables, as input to the complete model listed in Appendix 5. This may be used to simulate the behaviour of any industrial city. Finally, Appendix 6 combines the lists of terms for all sectors, which were presented in Appendix 3, to give a complete alphabetical list of all terms used in both versions of the model.

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PART I

The Dynamics of the Industrial City

Chapter 1

Brief History of Human Settlements

The city may be generally defined "as a relatively permanent concentration of population together with its diverse habitation, social arrangements and supporting activities occupying a more or less discrete site and having a cultural importance which differentiates it from other types of human settlement and association"(Mayer[1]). The city is the symbol and the carrier of civilisation. Indeed the very word civilisation in Latin means the culture of cities. From its origin onward the city may be described as a structure specially equipped to store and transmit the goods of civilisation but also capable of catering for the changing needs and the more complex forms of a growing society and its cumulative social heritage.(Mumford[2]).

The present chapter introduces briefly the transformation of human settlements through the years and is divided into 4 sections: Section 1 covers the process which led to the appearance of the first cities. Section 2 traces the development of the European pre-industrial city while section 3 is devoted to the emergence and development of the European industrial city. Finally, section 4 examines the forces behind the rise and fall of a city.

1.1 EARLY FORMS OF HUMAN SETTLEMENTS

Although urban settlements of some form had appeared in Egypt and Mesopotamia around 2000 B.C. the city as a solid organisation in its own right originated in Greek and Roman antiquity. Ishall be referring to this city as the ancient city. The appearance of the ancient city was the final stage in the process of transformation of human settlements which lasted for thousands of years.

Originally man was a roving hunter living in caves or hovels but in the transition period from the palaeolithic to the neolithic culture the first villages appeared. Those villages were clusters of families speaking the same language and participating in the same jobs. Division of labour was rudimentary; each villager owned his own land plot as well as his domestic animals and his only objective was to produce enough to feed his family. Scholarly opinions differ as how those villages were transformed into cities, that is inhabited places where people engaged in diversified activities. According to many authorities, however, the city was the result of the interplay between palaeolithic and neolithic societies (Comhaire and Cahnman[3]). In other words palaeolithic hunters armed with deadlier weapons than those of the neolithic peasants promised them protection on the condition that they work as serfs for their new masters. In the cases where conquerors and conquered were able to bridge ancient feuds and to establish bonds of brotherhood we have the creation of the city.

The Greek and Roman antiquity produced many great cities like Corinth, Athens, Sparta, Syracouse and Rome. Politically those cities -like the earlier urban settlements of Egypt and Mesopotania- were independent entities or city-states and sovereignity was vested in their inhabitants. Originally the social organization of the ancient city was based on birth and a few local families monopolised the power. Later, however, this traditional organisation was replaced by a new order based either on locality ("demos", from which the term "democracy" is derived) or on social class defined through property criteria. Relations between the city and the surrounding countryside were not peaceful; on the contrary citizens exploited the countryside. The most powerful city-states expanded immensely creating empires by unifying under their control vast stretches of territory. Perhaps the biggest of these was the Roman Empire, the administrative centre of which was Rome. Economically speaking Rome was a parasitic, unproductive city kept alive through heavy taxes paid by the provinces. By the 3rd century however, when economic crises reduced the tax returns, the life of Rome and consequently the life of the Roman Empire became problematic and eventually stopped. The disintegration of Rome which was the ultimate result of uncontrolled expansion and unscrupulous exploitation marked the end of the era of the ancient city.

1.2 THE PRE-INDUSTRIAL CITY IN EUROPE

With the decline of Rome the cities it had colonised or governed declined as well. Their existence was increasingly subject to invasion and the "very high roads that once had brought them security and wealth now only made easier the path of barbarian conquest" (Mumford[2]). The five centuries between the fall of Rome and the 11th century when European cities revived were a period of misery and terror. However the seeds of a new type of city were planted in that period in the form of the monastery. The monastery was indeed a new kind of settlement and during this stormy period it performed the function of the city in transmitting, if not enlarging, the social heritage. After the invasions of Norsemen in the 9th century almost all monasteries were fortified and the security of the wall had such a favourable influence that by the 10th century most of the monasteries had become towns. The cities movement, from the 10th century on, is a tale of new settlements being formed under the auspices of the feudal lord, usually a bishop or archbishop of the church, and endowed with privileges and rights that served to attract craftsmen and traders. Hence the medieval city became a selective environment gathering the better equipped and more skilled part of the rural population. A distinct characteristic of the medieval city was the high degree of its institutionalisation. Everybody had to belong to an association ; a manor, a monastery or a guild. There was no security except in association, and no freedom that did not recognise the obligations of a corporatelife. Outside the church the most important medieval association was the guild, a primarily religious fraternity which although adapted to certain economic functions kept its religious colour.

The guild and the protected economy of the medieval city could only function smoothly as long as the superiority of the city over the insecure life of the surrounding open country was maintained; in such a case industries were not tempted to seek new opportunities outside the city in spite of the sometimes heavy municipal restrictions imposed on them. By the 16th century, however, the disparity between city and country had been largely removed. This was due in part to improvements in transportation and in part to the improved security that had been established in the open country through the rise of a central authority. Industrialists, therefore, with enough capital to purchase raw materials andthe necessary machinery could establish their business outside the city borders. They were free from guild restrictions and could pay subsistence wages instead of the city rates. Gradually a large part of the industrial population came to earn its living outside the incorporated municipalities;even if those industries gave rise to urban settlements they remained competitors with the guild-protected cities. The growing importance of international commerce and the new economic ideology of mercantilist capitalism made even greater the ineffectiveness of the over -protected medieval cities, which were trying to solve within their walls problems that could only be solved by breaking the walls down and extending their sovereignty over a wider area,. The mounting problems brought tension and dispute between the various guilds, the beginning of a class war, corruption, the undermining of the authority of the church and finally the disintegration of the socio-economic basis of the medieval city.

As the medieval localism gave way to a centralised state, personal supervision was replaced by impersonal administration.The centralisation of authority necessitated the creation of certain administrative centres populated by civil servants and military personnel with a number of merchants and craftsmen serving almost exclusively their immediate needs. Therefore while the giuld-protected centres declined and industries were located outside the corporate municipalities, a few economically unproductive and purely consumption-oriented administrativecentres expanded rapidly and became the dominant cities of the new order.

1.3 THE INDUSTRIAL CITY IN EUROPE

As we enter the 18th century the typical city is still the administrative and trading centre of a predominantly rural economy. An interesting change, however, concerning the social structure of the city had been taking place; the landed aristocracy was losing its power to a new emerging ruling class of bankers and industrialists, whose only objective was increased production and maximisation of profits. At around the middle of the 18th century all the conditions were favourable for an industrial expansion. A vastly improved agricultural industry could sustainan increased non--agricultural workforce; a great improvement in roads and the development of canals that had taken place prov ided a transportation network able to meet,at a reasonable cost,the demands of an industrial expansion. The development of a strong financial system, the availability of capital and more important the eagerness of new capital holders to invest in industrial production and technological innovations could initiate the industrial expansion. Finally the free-trade policy had opened new markets for the goods that an expanded industry could produce in larger quantities than ever before. What was really needed yet was a new urban form to carry out this expansion. In their own image, therefore, the bankers and the industrialists created a new type of city, the first entirely production-oriented city in all history, the city of the Industrial Revolution. The first industrial cities appeared in England at around the middle of the 18th century and they were followed in the 19th century by similar urban developments in Germany, Belgium, France and the United States.

The underlying ideology of that period, which is clearly reflected on the organisation of the new city, was the belief that the "pre-ordained" harmony of economic order —or laissez-faire as it is commonly known— was sufficient to ensure the maximum public good through the efforts of self-seeking individuals. Obviously, therefore, the political base of the new city rested on the abolition of the guilds and the establishment of competitive market for goods and labour. Its economic foundations, on the other hand, were the exploitation of mineral resources, the use of steam as a source of mechanical power and the decreasing cost of production resulting from the vast economies of scale. Minimum interference from the local and national government meant that every single action —such as the location of factories, the building of houses for the workers, the supply of water and even the collection of garbage— should be taken by private enterprise seeking profit. The factory became the nucleus of the industrial city of the laissez-faire era; it claimed, and eventually spoiled, the best sites and the people were simply its servants. The only objective of the city was the maximisation of the factory profits regardless of any cost to people and environment. For many years the inhabitants of every industrialised urban area had to pay a very high price for the convenience and the economic gains of the manufacturer. Indeed during the 19th century the degradation of the urban environment reached a very high level. In the words of Patrick Geddes[4] "slum, semi-slum, and super-slum to this has come the evolution of the cities".

Reaction against the high level of urban degradation and more generally reaction against the underlying socio-economic ideology of that period produced a series of new socio-political forms favouring public involvement in the running of the country's economy. In urban terms this change of attitude meant the introduction of planning measures in an attempt to correct the social consequences of the 19th century uncontrolled growth and to control any further urbanisation (Berry[5]).

The impact of planning and control on urban development throughout the world and the appearance of two new types of industrial city —the city of the welfare state in Western Europe and the city of socialism in Eastern Europe— which place strong emphasis on the social welfare of their inhabitants will be discussed in detail in chapter 10.

Concluding this section however I may say that increased state control and the growing importance of service industries have revived the need for the administrative centre either in a pure form or most likely as an integrated part of the new industrial city.

1.4 THE PROCESS OF THE CITY DEVELOPMENT

I have so far outlined the process of transformation of human settlements from the cave to the contemporary city. In this last section I shall try to analyse the general forces that lie behind the growth and decline of industrial cities.

Various attempts have been made to summarise the course of city development and to correlate it with the rise and fall of civilisations. Such classifications, however, although intellectually stimulating, have several shortcomings and must be treated with caution. Their main shortcomings are that they implicitly assume:

(i) ...that social change occurs gradually and continuously from uniform causes that are endogenous to the society or culture under consideration. This assumption is critised by many social theorists, who claim that "there is no historical evidence to suggest that macro-changes in time are the cumulative results of small-scale linear micro-changes" (Nisbet[6]) and also that "the most notable social changes have occured abruptly, involved catastrophic discontinuities and were the result of exogenous events" (Nisbet[6], Drucker[7]).

(ii) ...that each city is simply a block of the cultural structure unified within itself to form a part of a consistent whole. The city, however, is more than that. It is both the generator and recipient of societal changes; moreover, it has the power of reorientation and adaptation to any new cultural outlook. Historical evidence suggests that the development of a particular city is not only a function of exogenous forces but also of an endogenous process of reaction to exogenous changes (Mumford[8]). Depending on the interaction between exogenous and endogenous forces the development of a city may be continuous or discontinuous. A city may decline with the fall of the dynasty which supports it or with the change of the socio-political system it expresses. Alternatively, it may survive the blow of dynastic or societal changes and continue to exist in a renewed form through more than one cultures. It may even collapse for a variety of reasons in the middle of a culture.

Let me now give examples of cities that have displayed these three types of development (Chandler and Fox[9]).

Rome is a typical example of a city that declined with the fall of the civilisation whose masterpiece it was. Angkor and Machu-Picchu are two similar examples. Angkor, the capital of Cambodia from 889-1431 and one of the 10-20 largest cities in the world during the period 900-1350, was abandoned in 1433. Similarly Machu Picchu, the Inca capital, was abandoned after the decline of the Inca civilisation.

Damascus is probably the most ancient of towns which have survived through many cultures. Already venerable in St. Paul's day it always remained an important city and indeed among the 10-50 largest cities of the world during the period 600-1800. Aleppo, is another example. It came to prominence around the 7th century, became the capital of Syria in the 10th century and remained among the 50 largest cities of the world from 600 to 1800. Cairo was founded in the 10th century, reached a peak around 1350 (500,000 population) and inspite of Turkish and French occupations has remained a great city to this day. Marseilles, one of the provincial towns of the Roman Empire, not only survived the blow of the Empire's disintegration but also experienced a period of prosperity after the fall of Rome and played a significant part in the outburst of Provençal culture in the early Middle Ages. Finally in Britain Bristol, Aberdeen, Edinburgh and of course London may be classified as surviving cities.

Finally, let me identify cities that declined in the middle of a culture. Fatehpur Sikri is a typical example. Founded in 1569 as Akbar's royal residence it reached its peak in 1583 with a population of around 300,000 but 10-15 years later it was in ruins and has never recovered since. The reason for that dramatic decline was the transfer of the royal residence to Agra which in turn experienced a phenomenal growth with its population increasing from 70,000 in 1550 to 500,000 in 1600. Palmyra is another example of precipitate decline . One of the most important trading centres in Syria around 330 BC, it collapsed as a result of changes in the principal routes of that trade. In Britain,Winchester which had a population comparable to that of London around 1050 but later declined beyond recovery may be classified in this group of cities. The same may be said for various northern industrial cities which developed rapidly during the early stages of the Industrial Revolution but declined during the 20th century. The degree and the rapidity of their decline is placed in the right perspective only if we take into account the massive Government efforts aiming at preventing it.

Summarising I can say that city development and the rise and fall of civilisation are not identical processes. In the words of L. Mumford[8] "Cities exhibit the phenomena of broken growth, of partial death, of self-regenaration. Cities may have sudden beginnings from remote gestations; and they are capable of prolongations as physical organisations,through the life-spans of more than one culture". When, through the process of destruction great cities sink into ruin "others (which) stagger from the blow, will nevertheless continue to live; indeed, theymay live more intensely". Historical evidence suggests that many cities which do decline are over-dependent on specialised activities. The loss in importance of those functions due to general social changes or even personal whims coupled with their inability to attract new activities, is the reason of their fall. The modelling of the changes in the development of a city resulting from discontinuous exogenous forces is beyond the scope of the present thesis and so is the modelling of a city that survives through several cultures. My main objective is the study of the development of a city inside the life-span of a culture and subject to continuous exogenous forces. The period I have chosen spans from around 1800 to today; in other words it covers what we may call the "culture of industrial society". The proposed model is based on data and experience from British cities but it may well be applied, with minor modifications, to cities of other countries which have followed a similar course of socio-political development.

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Chapter 2

Mathematical Models in Urban Studies

As operations in business, industry and government become increasingly complex, the need for reliable mechanisms to help us to understand and control them arises. Experience and intuition although useful in many cases cannot be used as the only basis on which the control of various complex operations can sensibly be exercised. More objective methods of analysing the underlying principles of the operations involved are required.

In recent years the building of models has become one of the most important methods of studying the behaviour of complicated systems. A model may be generally defined as a representation of, or an abstraction from, at least one aspect of a real situation. In this context the situation may be an object, event, process or system. According to the means used for the representation of the real world models may broadly divide into two groups: physical models and mathematical models. In physical models, the physical characteristics of reality are represented by the same or analogous characteristics. In mathematical models, on the other hand, the structure of a real world system is expressed as a set of mathematical equations. For the purposes of this study we are, obviously, more interested in this latter group of models.

2.1 GENERAL CONCEPTS OF MATHEMATICAL MODELS

Mathematical model building is not a clearly defined subject; it is rather an art and above all the art of simplifying complicated problems. The simplicity of a mathematic model is based on the fact that only properties of the real situation relevant with a specific problem are represented. Obtaining a good balance between accurate representation, simplicity and mathematical manageability is one of the most difficult aspects of model building. The construction of a mathematical model implicitly assumes the existence of a certain underlying theory which explains the relationships used in it. Solutions derived from the model are therefore consequences of this underlying theory.

A mathematical model usually consists of variables, parameters, structural relations and an algorithm.

Variables are quantities which represent activities of the given system. They may be distinguished into independent variables, whose values are given as input to the model, and dependent variables whose values are determined by the model or are given as output.

Parameters are quantities which generally do not vary. However, they may be occasionally revised so as to readjust the structure of the model to the changing environment.

Structural (or Functional) relations are relations between the dependent and the independent parameters of the model and represent its underlying theory.

Finally, algorithms are series of procedural steps which will eventually lead to the solution of the model's problem.

The potential uses of mathematical models cover a wide range; according to the purposes for which they are defined mathematical models may be divided into the following three groups:

Descriptive models

Predictive models

Planning or Decision models

The main objective of Descriptive models is to facilitate the understanding of the mechanisms governing the behaviour of a given system. Such models are a necessary prerequisite for any other type of model because it is impossible to predict, explore or plan the future states of a system without a clear understanding of its underlying structure.

Predictive models' primary target is to forecast the future states of a given system. They are usually distinguished into predictive extrapolative models which are based on the assumption that the present trends will continue in the future and predictive conditional models which specify in more detail the cause and the effect mechanisms.

Finally, the primary objective of the Planning models is to determine the optimum configuration of a system under a given set of constraints. The validity of this solution depend on the adequacy of the model in representing the real system.

Apart from the classification according to their potential use, mathematical models may also be classified in several other ways. Classification is sometimes made in terms of the nature of the system they model such as continuous versus discrete, or deterministic versus stochastic. In other cases the distinction is based on the treatment of time and models are characterised as static or dynamic respectively.

Further elaboration on the various types of mathematical models is, however, beyond my scope and I shall conclude this introductory section by looking at various methods for their solution. The three most important methods which enable us to determine the solution of a mathematical model are (Reif[1]):

Analytical Method

Numerical Method

Simulation Method

The analytical method consists of directly proceeding to the solution of the system of equations by the use of calculus or other means. Although a neat and elegant method, it is only applicable to simple models free of non-linearities and discontinuities.

The numerical method consists of trying a number of possible solutions and selecting the best (or approximately best). The selection is usually made by either a trial-and error procedure or an iterative procedure. Numerical method is usually applied to models with mathematically complicated structure.

Finally the Simulation method consists of step-by step following of the changes in the state of a system over time. Simulation is a way of manipulating a model in such a way as to obtain a sort of a "motion-picture" of reality. The simulation method is especially suitable for systems whose behaviour can only be represented by complex non-linear models.

2.2 A REVIEW OF URBAN MATHEMATICAL MODELS

In recent years urban researchers have come to the conclusion that mathematical models are probably the best way of describing the structure of a city and studying its development. This turn to the use of mathematical models, as tools for facilitating urban research, although stimulated by recent advances in computer technology, is probably due to the complexity of the problems facing urban researchers (Batty[2]). A careful analysis of the structure of a city reveals that it is impossible to study effectively any of its parts in isolation because all parts are strongly interrelated. This suggests that a much more fruitful approach would be to consider the city as a system displaying certain patterns of behaviour and then try to model its structure and function. The theory on which the model is built represents the model builder's own understanding of how the urban system actually works.

The behaviour of an urban system depends on the changes of its statethrough time. The manner, especially, in which those changes take place is of considerable importance. In spite of its importance however it was not until recently that models treating the process of change in an explicit way (i.e. Dynamic models) appeared. Most of the early urban models were static. The underlying principle of a static model is to consider the city, at each point in time, as a system in equilibrium which is then disturbed by the addition of several elements of change. The assumption that the system tends rapidly to equilibrium is implicit in models of this kind and the process of return to equilibrium after each disturbance is unspecified.

A typical example of a static model is Lowry's[3] "Model of Metropolis". This model was developed by I.S. Lowry as a part of a modelling system to generate alternatives and to aid decision making in the Pittsburgh Comprehensive Renewal Program. It is expressed as a set of nine simultaneous equations with three inequalities as constraints and it simulates the pattern of a city's development at a particular point in time. Given the level and geographical distribution of basic employment within a city as input,the model generates as output the level and geographical distribution of retail employment and households. The two key concepts of this model are the Economic Base Hypothesis and the Multiplier. The Economic Base Hypothesis expresses the fact that households and services can be uniquely derived from the Basic Emplpyment while the Multiplier scales Basic Employment to Total Employment. Lowry's model with its well-defined structure and its simplicity in terms of data requirements has been proved very popular and has been adopted, modified or not, by planning authorities in Britain and in many other countries.

Static models, however, although useful for mainly educational purposes are an over-simplification of the real world and of rather limited practical use. The growing feeling among researchers that time is too important a dimension to be left out, together with thefact that most of the real decision problems faced in an urban system are related to its dynamic characteristics rather than to its static equilibrium conditions, have recently stimulated a strong interest in construction of Dynamic models. The remaining part of this section will be devoted to a brief review of five urban dynamic models that have been constructed. The selected models are different in their design and provide a comprehensive view of the spectrum of approaches to urban dynamic modelling.

The Time Oriented Metropolitan Model (TOMM) is essentially a modification of Lowry's model. It was originally developed by Crecine[4] for the Pittsburgh Community Renewal Program and several improved versions of it have appeared since them. It is expressed them over one year intervals. It is mathematically expressed as a set of sequentially-solved difference equations relating population, basic employment and service employment boththrough time (via the economic base hypothesis) and through space (via gravity models which simulate the flows between the various activities). Although its underlying approach to dynamics is basically similar to the approach used in the two models described above, the way in which the dynamics are modelled is more advanced and two dynamic effects are introduced. Firstly there is the influence of existing stocks of activities on their future distribution; this is an effect incorporated in both TOMM and EMPIRIC models. Secondly, however, there are the repercussions from previous changes in activity which are still working in the system; this is a factor which was not taken into account in any of the previous models.

All three dynamic models introduced so far have a common characteristic. In their attempt to model the process of urban change they all follow the so-called macroanalytic or Social Physics approach. In other words they attempt to simulate in very empirical manner the statistical regularities observed in the geographical distribution of the various urban activities. The principal critism of such an approach is obviously its lack of causal structure. An alternative approach to urban modelling is the so-called microanalytic or Behaviouristic approach. It is based on the assumption that the larger groups willact in ways which can be derived from an understanding of the individual unit. The main difficulty of the behaviouristic approach is that the system of relative values on which the rational choice of the individual is based must be specified in every detail before the model can be implemented.

An urban dynamic model which follows the behaviouristic as a set of mainly first-order difference equations which are solved sequentially and iteratively. Its main objective is to model the changes in the stocks of the various urban activities over 2-5 year intervals. Although basically using the same mechanisms as Lowry's model, TOMM also introduces an important distinction between location of new activities and relocation of existing ones. Its major contribution was the succesful design of a simulation that linked together several submodels in order to initiate overall urban development.

The EMPIRIC model was designed by Hill[5] for the Boston Regional Planning Program and has been revised several times since then. It also is based on a system of first-order difference equations but its organisation is more formal than that of TOMM and the solution methods adopted recognise the simultaneous nature of urban relationships. Unlike TOMM, the EMPIRIC model treats the concept of spatial interaction implicitly and relocation of existing activities is ignored. It is fundamentally a statistical model that derives changes based on the level of activity in each zone as a function of the changes of other variables such as accessibility, provision of services etc. . Because of its simplicity and its reasonably accurate presentation of reality this model has been popular in the modelling of American cities.

TOMM and EMPIRIC were two of the earliest attempts at the modelling of the process of urban change and naturally their main limitation lies in the rather elementary approach to modelling the dynamics of this change.

The model built by M. Batty[6] and the Urban Systems Research Unit of the University of Reading is designed to simulate the changing structure of urban activities and interactions between approach is the NBER Urban Simulation Model which was developed by G.K. Ingram, J.F. Kain and J.R. Ginn[7] for the National Bureau of Economic Research. Data collected in Detroit were used extensively for the calibration and testing of the several versions of it. The NBER model consists of seven complex and interrelated submodels, each of which replicates an aspect of urban development. According to its designers their "principal theoretical interest" in constructing this model "has been to understand the effects of the spatial structure of urban areas of long-term trends in the level and spatial distribution of employment, of changes in transportation technology, of increases in income and of the growth in employment and population". The analytical core of the model is the housing market and most of the decisions simulated by it are related to the determinants of housing demand or supply location. The algorithms used to describe the behaviour of the housing market are derived from microeconomic theory and Linear Programming techniques are used to translate this behavioural process into an operational form. Technical constraints on data storage and processes are major limiting factors in the operation of the NBER. The extent of the problem can be better appreciated by a specific reference to the dimensionality of one of its earliest versions which simulated 96 types of households employed in 11 industries located at 20 work places and 40 housing bundles available in 50 residence zones. These relatively modest model dimensions aggregate to 1,920,000 unique combinations of work zone, residence zone, family type and housing bundle. Improvements in computer technology have but not completely resolved such dimensionality problem.

The four dynamic models presented so far concentrate on the city itself and the spatial distribution of the various urban entities but they virtually ignore the interaction of the city with its surrounding environment. This aspect of a city's development is covered extensively in Forrester's[8] model. The model begins with an empty city of fixed land area situated on an infinite plain capable of supplying population to or absorbing population from the city. Although occupies 100,000 acres it has no spatial dimension. The city keeps growing until it reaches an equilibrium state which Forrester calls a "standard condition". He then introduces several urban programs and simulates their effects on the system over a period of 50 years starting from the equilibrium state. The results he obtains are highly controversial; urban programs traditionally thought to be of unquestionable value are shown to cause further deterioration, whereas programs subject to contention are shown to improve the urban system considerably. Forrester justifying the results maintains that they are due to the counter-intuitive behaviour of that complex system, the city. Forrester's model was a pioneer effort and naturally has certain shortcomings. The main reservations however, concern not its underlying methodology but the interpretation, by the author, of the results obtained when the model was used to test the effects of various urban programs on the development of the city. Implicit evaluation criteria employed to judge urban programs, and the lack of a clear overall objective for the city, have confused the interpretation of the results. In spite of its shortcomings, however, Forrester's model represents a very interesting step towards a comprehensive and reliable urban simulation model (Ingram[9]).

In designing the model which will be introduced in Chapter 4 my emphasis was placed on the analysis of the mechanisms governing the attraction power and consequently the development of an industrial city over a long period. Land availability and land use are obviously among the factors which influence the growth of a city but there is no evidence to suggest a significant interdependence between locational distribution of urban entities and the long-term development of a city. In view of this fact, and in view of severe time limitations, the process of spatial distribution has not been included in the proposed working model. Location, however, is an important subject in its own right and in order to complete the picture of urban development Chapter 9 presents a brief analysis of this process together with broad guidelines for its eventual modelling.

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Chapter 3

Growth and Decline in the Industrial City

3.1 THE CITY AS SOCIO-ECONOMIC UNIT

The term industrial city, as I have mentioned already, refers to the new urban form which appeared for the first time in England around 1800 and it was characterised by large concentrations of people predominantly occupied in mechanised factories. The industrial city, as every type of city, has to perform a double function; economic and social. In the words of L. Mumford[1] "it is an economic organisation, a theatre of social action and a symbol of collective unity: on one hand it is a physical frame for the commonplace and economic activities on the other it is a consciously dramatic setting for the more significant actions of human culture". During the 19th century the development of the industrial city was centred around continuous industrial expansion and maximisationof profit for the industrialists. The growth of the first industrial cities was an almost automatic process; the heavy dependence of industries on natural resources led to their concentration in areas rich in minerals. At the same time the remarkable increase in the size of the country's population coupled with the intensification of the Enclosure Movement and the slump in farming after the Napoleonic Wars forced many people to follow the industries. The additional fact that wages were generally higher in industry than in agriculture made this "drift to the cities" even stronger and led to a phenomenal growth of their population. However as industries became less bound to natural resources their location became less constrained and more open to choice. In addition the fact that the social function of the city, so much neglected during the 19th century, regained some of its importance made the attraction of people more than a mere consequence of industrial concentration. Consequently during the 20th century the growth of an industrial city became less the result of natural advantages and more subject to its power to attract both the industries and people through a combination of a wider range of economic and social factors.

Let me look at the factors now influencing the location of industry. Empirical evidence (Sant[2],Townroe[3]) suggests that although purely industrial factors such as accessibility to natural resources, land availability, transportation facilities etc. remain important, the availability of suitable labour has also become a primary concern. Therefore, social and environmental factors indirectly influence industrial location. A healthy environment has become a powerful stimulus of capital flow and as Richard Atkinson[4], the county Durham Planning Officer, has found "industrialists are increasingly critical of the environment they choose to establish new projects and potential industrial development has been lost simply because the quality of town was not good enough". The new attitude of the industrialists is perfectly illustrated in the following extract from B. Wilkinson's[5] book "The Town that was murdered". When she critised Lord Nuffield for establishing his new car plant in Oxford instead of bringing much needed work to Jarrow or South Wales, a high official of the Morris Cowley works answered: "Oh, I don't suppose Nuffield would have minded. He can live where he likes. But it would have been hell for us. He coudn't have got a first class manager or technician to spend his life in Merthyr Tydvil". When E. Wilkinson further suggested that they could improve a city if they had to live there, the official answer was "When I' ve finished work I want some life ... not to run a Mutual Improvement Society..." Further analysis of the process of locational choice suggests that a distinction must be made between a list of factors or requirements that is seen by the managers of a firm as a minimum for all locations and those additional factors which may tip the balance between one alternative location or another. In other words the process of industrial location appears to be a two-stage process whereby "the final choice is made from a small group of possible locations all of which satisfy a basic set of criteria" (Townroe[3]).

Let me now move on to the factors influencing the movement and location of households. Although job and pay prospects are always among the most important factors —underlying therefore the importance of industrial investment— a new set of factors such as housing, social amenities, healthy environment are becoming increasingly significant. Although the two-stage process described in the case of industrial location is not explicit in the case of people the existence of certain minimum standards is beyond doubt. A Government Survey (Harris and Clausen [6]) showed that around 50% of the people who would generally consider moving with their present employer were not prepared to move to certain particular areas.

More important, no specific reasons could be given for this attitude but most of the people justified it in terms of "general dislike of the area" or "lack of appeal" for them. The survey suggested that "it may well be that lack of knowledge of the facilities offered, the amenities and the general background of the area and the people who live there, or impressions gained from television, may have distorted the picture. If it is really important for movement to be made towards those areas then an extensive campaign giving a true picture of the areas might be needed before workers are approached to move there". Whether the picture is distorted as the survey suggests or it is true (in which a case much more than a campaign will be needed) is not my concern at this stage. What I want to point out is that as in the case of industrial location, people are also prepared to consider moving only to areas satisfying a set of basic criteria.

The apparent existence of sets of minimum requirements for both people and industries, together with the ever increasing interdependence between industrial and residential location seems to suggest that a general set of basic criteria applicable to both industries and people could be defined. A city satisfying this general set of criteria will be considered as a potential final choice for both people and industries. The need for such an overall approach to the study of the city and its problems has been realised by L. Mumford[1] when he was writing in 1939 that "the elemental unit of planning is the city itself, because it is only in terms of this more complex social formation that any particular type of activity has significance. And the aim of such planning is not the efficiency of industry by itself, or the diminution of disease by itself, or the speading of culture by itself: the aim is the dramatisation of communal life so that no activity will fail to contribute to the reciprocal support of citizen and community". Almost 40 years later D.Eversley[7], director of the Centre for Environmental Studies, speaking at the University of York about the reasons for the decline of many of Britain's industrial cities identified this lack of reciprocal support between business, people and the city as the basic problem. "We are talking", he said, "about an essentially psychological problem which we call blight. In reality it is a loss of confidence of the business community, of individuals, of groups of people within the local community in the future of those areas. This leads to accelerated migration, rapid shifts of investment and physical neglect". Any attempts to tackle the "city syndrome" by attacking one problem at a time is bound to fail as long as the confidence of people and industries in the future of the city is lost. In other words, as long as the city does not satisfy the minimum standards set for the attraction of new industries and skilled employees to run them,piecemeal improvements will not avert the decline. "The injuction to see life steadily and to see it whole", writes J.L. Fisher[8], "applies with special reference to life in the city, where babel and confusion seem always on the verge of taking over. Plato put the essential question long ago: How can we arrange things so that each individual can become one instead of many and their city can become one instead of many? The answer of course... is the search for unity and cohesiveness in the midst of richness and diversity".

Having outlined the relevance of a general set of basic criteria for the study of a city's development I shall now concentrate on their nature. As I have already mentioned some of those criteria concern the economic function of the city while the others concern its social function. The two functions of the city, however, are not always compatible; on the contrary the idea of a conflict between them is widespreadin Urban Literature. "City is ... a place for work and social interaction. Thus working and living must be compatible, but often the factories for work make the environment for living unpleasant or unbearable" (Spilhaus[9]). Instead of offering a balanced life the industrial city usually takes with one hand what it offers with the others. "One climbs its golden tree with such difficulty that, even if one suceeds in plucking the fruit, one can no longer enjoy it" (Mumford[1]). In the words of C.D. Harris and E.L. Ullman[10] "Cities are paradoxes. Their rapid growth and large size testify to their superiority as a technique for the exploitation of the earth, yet by their very success... they often provide a poor local environment for man". Professor B. Harris[11] expresses the same idea of conflict when he writes that "our cities are growing mightly in population, in wealth and in geographic extent but with social and environmental consequences which most of us find distasteful". Clearly, therefore, the most pressing problem of an industrial city is to achieve a balance between its economic and social functions "in such a way that the advantages of urban concentration can be preserved for the benefit of man and the disadvantages minimised" (Harris and Ullman[10]). In the words of J.L. Fisher[8] "a city in which land is fouled,...the aesthetic sense violated and in which the whole urban arrangement is haphazard and messy is not likely to support individuals however high their level of material welfare may be".

Many examples of that inherent conflict between the industrial and social development of a city may be given. The construction of a motorway, for example, may improve the communications of the city and consequently its industrial potential but at the same time it may cause a deterioration of its environmental conditions. Similarly, the use of a large proportion of the land available for industrial purposes may improve the industrial potential of the city but at the same time it will restrict the land available for houses, open spaces, recreational grounds etc. and hence it may lower the level of its social amenities. Those were two examples of a rather direct conflict between the factors influencing the industrial potential of a city and those influencing the level of its social amenities. More generally, however, a kind of indirect conflict between them may also be detected. The improvement of both sets of factors depends largely on the amount of expenditure the city is prepared to place on each one of them. Since however, the budget of a city is always limited a conflict of priorities is bound to develop.

Having justified the need for a general set of basic criteria and having also underlined their conflicting nature I shall conclude this section by discussing the potential advantages of the use of such a set of criteria for the study of a city's development. Apart from simplifying the analysis of a city' behaviour, such a general measure of performance has the following two advantages:

(i) It gives an early warning of any potential danger of decline.

(ii) It gives the "true" picture of the city and helps us to detect the causes and not only the symptoms of any existing problems.

An early and correct diagnosis of a problem is perhaps the biggest step towards its solution. In the case of urban development however, the seeds of decay are usually planted during a period of prosperity and no action is taken against them until it is too late. H. Mess[12] writing in 1923 about a situation in industrial Tyneside concluded that "the Tyneside we deplore today was the product of a long period of prosperity. In the years when mammoth liners were being launched, during the great expansion of the coal industry in the heyday of the chemical industry, this Tyneside was brought into being". Therefore a monitoring device which will alert us at the first sight of danger is a device of great importance. In section 3.3.I shall return to this general set of basic criteria and I shall try to define a measure of the true state of the city as a function of the factors of this set.

3.2 POTENTIAL DISCONTINUITIES IN THE DEVELOPMENT OF AN INDUSTRIAL CITY

Industrial cities grow and decline. As I have mentioned already in Chapter 1 historical evidence suggests that the development of a city is a function of both exogenous and endogenous forces. My main objective in this section is to concentrate on the critical points of the development of an industrial city —namely its original "take off" and its transition from a growth to a decline stage— and to decide whether discontinuities may occur at those points. I believe that such an analysis may be best pursued in terms of a specific city rather than abstractly. The city I have chosen is Oldham whose development may be considered typical of a large number of northern industrial cities. The choice of such a type of city was intentional because its development has been characterised by wide fluctuations.

Figure 3.1 represents the population of Oldham over the period 1801-1971. Figure 3.2 shows the average annual rate of its population changes for each decade over the same period as well as the corresponding rate of change due to migration only. For the drawing of the latter graph the rate of natural increase for Oldham was required and this has been taken as identical to that of the country as awhole.

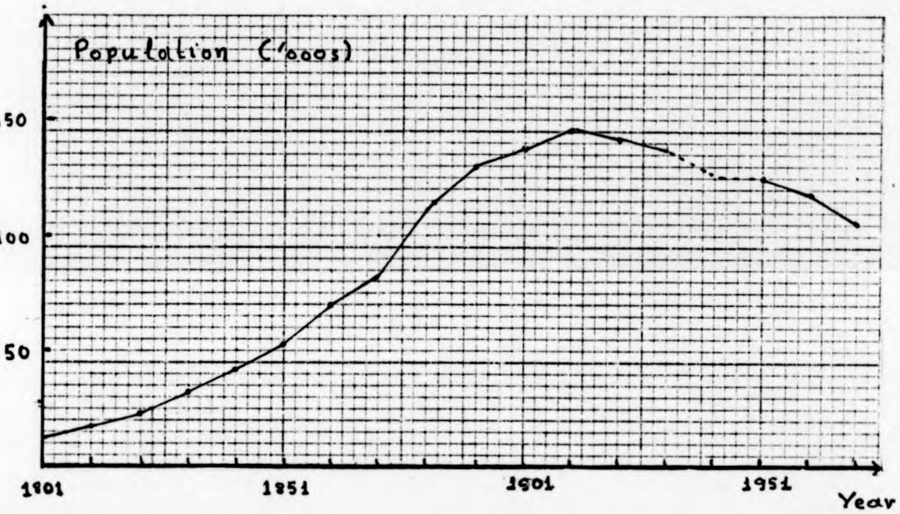

Figure 3.1 Population of Oldham (1801-1971)

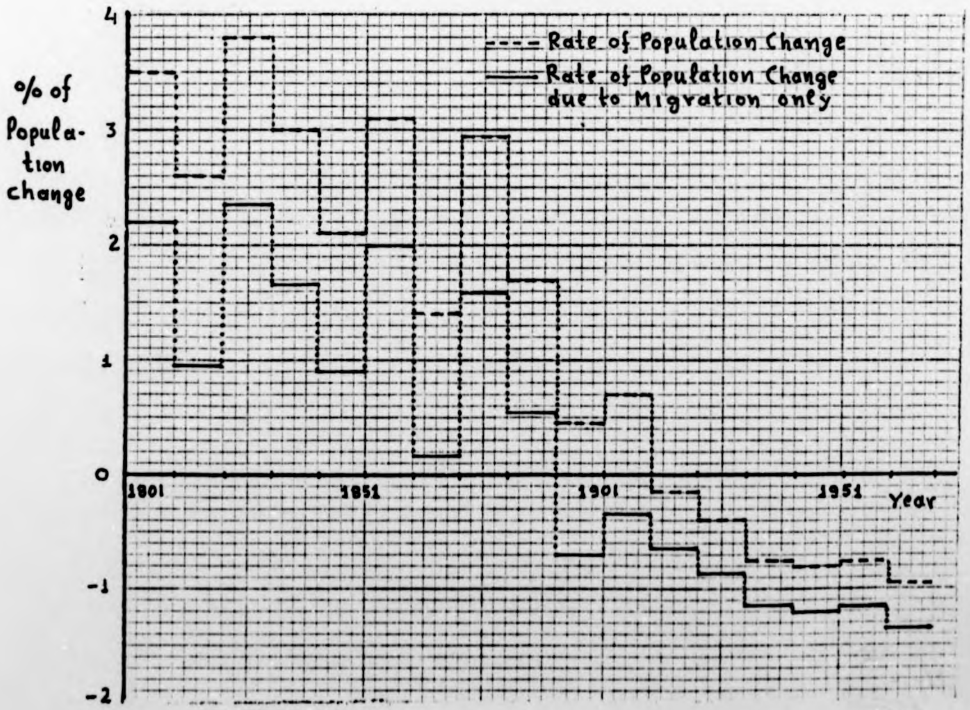

Figure 3.2 Changes in the Population of Oldham

The graph of population changes due to migration only provides the best representation of the development of the city and I shall concentrate on that; more precisely I shall concentrate on those of its sections which cover the periods around 1800 and 1900 respectively. The graph shows a high positive rate of migration around 1800 which may be taken as an indication that the city went through a period of rapid growth. Since, however, no consistent population data is available for Oldham for the period prior to 1800 the question of continuity or discontinuity cannot be conclusively answered on the evidence of this graph alone. If onthe other hand, we consider the County of Lancashire as a whole the situation becomes clearer. According to historical evidence (Deane and Cole[13]) the average annual rate of migration for this County was -1.2‰ during the period 1751-1780 as compared to +11.6‰ during the period 1781-1800 (the highest in any County outside London) and +6.2‰ during the period 1801-1830. Such evidence, if it may be taken also as characteristic of the city of Oldham, suggests not only a highly accelerated rate of growth —which may not always be considered as a conclusive evidence of discontinuity— but indeed a reversal in the trend from net out-migration to net in-migration . Net in-migration continued uninterrupted for the next 70-80 years but as we approach the turn of the century the graph displays a switch to net out-migration; such a reversal of the trend may be taken as an indication that the city has entered a period of decline.

Reversals in the trend of population changes due to migration alone are strong evidence of discontinuities in the development of a city.Furthermore if we take into account that such reversals are only delayed and inherently smoothed consequences of changes in the attraction power of the city then we may expect that a more accurate measure of this attraction power would display a more dramatic change. In the remaining sections of this chapter I shall introduce such a measure and I shall study its behaviour. A very interesting discussion on the subject of continuity versus discontinuity in the process of economic growth with special reference to the case of Industrial Revolution may be found in W. Rostow's[14] book "The Stages of Economic Growth"

In the remaining part of this section I shall discuss how the idea of discontinuity has been treated in the Urban Research so far. The concept of discontinuity in the development of an industrial city is certainly not novel in Urban Literature. As I have mentioned in Chapter 1 L. Mumford[1] one of the greatest students of urban development concluded that "cities exhibit phenomena of broken growth, of partial death, of self-regeneration". Furthermore, writing specifically about the industrial city of the 19th century he stated that "it is by its nature in a state of permanent unbalance" and its main problem is to "reduce itstendency to swing violently from prosperity to bankruptcy. J.G.Williamson[15] referring to the rather more general, but indeed similar, concept of regional development concluded that although the early stages of national development generate increasingly large differentials in favour of the northern regions "somewhere during the course of development there is a reversal in the pattern of interregional inequality". In the case of England the pattern of regional equality after the Second World War has been greatly influenced by Government control; if however we confine ourselves to the period 1780-1940, then the sudden reversal of the trend is obvious and indeed this period may be divided for certain regions, and indeed many cities, into "two sharply contrasting phases"(Lee[16]). D. Eversley[7] referring to the problem of urban blight (or in its own words to "the loss of confidence of the whole community to the future of certain urban areas") concluded that "if the blight hole happens to be in a development area, Liverpool, Glasgow or Tyneside we seem to take it for granted that something needs to be done about it. It is the sudden emergence of the blight holes in what we thought were the "safe" areas that has taken us by surprise". Finally, to end this brief compilation of some of the views on discontinuity in the development of an industrial city I quote Professor B. Harris[11] who has suggested that "an aspect which deserves more consideration and analysis is "the importance of non-linear and time-dependent systems. Even elementary considerations suggest that interactions in the urban systemare strongly non-linear. Yet we still cast much of our analysis in linear terms because these systems are more tractable". Concluding this section I must mention that two mathematical models concentrating on the discontinuous development of cities —although not industrial cities— have been constructed. The first by J.C. Amson[17] who studies the city as an "urban gravitational plasma under opposing civic forces of cohesion and dispersion" and the second by A. Mees[18] who studies the growth and decline of Medieval cities.

3.3 THE CONCEPT OF A CITY'S IMAGE

A concept of central importance for my model is that of a city's Image. The use of the wordImage in this context is completely different to that usage initiated by K. Lynch[19] and associated with mental maps. As I have mentioned already in section 3.1 the growth or decline of an industrial city depends on its power to "pull" and retain both industries and the right blend of people to run them; this pulling power depends on what I call the Image of the city. At each point in time the city "sends out" its Image and depending on its impact on the people (both employers and employees) the city may be considered Attractive or Repulsive. In the words of Perloff and Wingo[20] "the growth (of a metropolitan region) will depend on the nature of the net flows of investment and migrants between the region and the rest of the world which are frequently influenced by something as insubstantial as the kind of image a metropolitan region puts forth ... In the last analysis the image will reflect the quality and vitality of planning in the region and especially its awareness of its role in the development process. Then planners can work specifically to create the kinds of public capital and environmental conditions to attract new capital —such as creation of industrial estates with homes not too far distant— and to retain existing industries through industrial redevelopment to make expansion and high-quality public services possible".

One may argue that since people "receiving" the image of the city belong to various distinct groups (i.e. employers, unskilled workers, skilled workers etc.) and are sensitive to different factors,the impact of the Image of the city on the members of each particular group will be different. Whilst this is plausible, evidence presented in section 3.1 suggests that all groups of potential movers react similarly to a basic set of factors; more precisely a set of minimum standards largely common to all groups must be satisfied if the city is to be considered as a potential choice by any ofthem. them. To reconcile these two views I refine the concept of a city's Image by introducing the following two concepts:

Basic Image

Specific Image

Basic Image of a given city measures the degree to which the city satisfies a set of basic criteria common for all movers. A city satisfying those criteria is considered by all potential movers as worth a closer examination and as a potential final choice.

Specific Image of a given city, as perceived by a particular group of potential movers, measures the degree to which movers belonging to that particular group consider the city as their best final choice. This Specific Image however, although a function of specific factors appealing mainly to members of that group, is primarily a function of the Basic Image. A complete list of the factors which are thought to influence the Basic Image and Specific Images of a city will be given in Chapter 6.

Basic Image is a rather abstract concept which expresses the actual state of the city; a physically realisable measure for the Basic Image is difficult to find. Specific Image on the other hand expresses the opinion of the potential movers about the city and is theoretically measurable. Net change in the number of the members of each group due to migration may provide a good measure of their respective Specific Images. Such information however, is not readily available from the usual statistical sources. What may be measured more easily is the net change of a city's population due to migration during each time period. Such a change however is of very little importance as a measure of the real state of the city. The perception and reaction times to any change are different for the various groups of potential movers and are particularly long for certain vulnerable minorities who lack real choice in place to live and work. Hence, the measurable changes of the city's population due to migration may be generally considered as the delayed and considerably smoothed consequence of changes in the Basic

Image. It will be argued later that Basic Image is a function unstable for a wide range of values around zero; hence, its transition from a positive to a negative value may, in certain cases, be considered as a sudden jump. If the model is correctly built one would expect that changes in the Basic Image of a city and measurable changes of its population due to migration would generally agree in sign (i.e. both positive or both negative). The study of the mechanisms governing the shaping and the changes of a city's Basic Image is a task of imperative importance. By keeping the Basic Image of a city attractive we make sure that, in spite of possible flunctuations in the effectiveness of various specific factors and unexpected external adversities, the city may retain its overall pulling power, renew its ageing industries, maintain the right blend of workforce and finally overcome any difficulties. As soon as the Basic Image becomes repulsive, however, the situation changes completely; the city enters a vicious circle of deprivation and decline the breaking of which is extremely difficult. Piecemeal approaches aiming at the breaking of this vicious circle through the improvement of certain specific factors may provide a temporary cure but the only and lasting solution to this problem is the restoration of the Basic Image.

3.4 BASIC IMAGE AS THE OUTCOME OF A CONFLICT

I have so far introduced the Basic Image of a city as a function of a number of, yet undefined, factors which influence the movement of people and industries. In a country like Britain mobility is essentially a voluntary process. Government intervention may only be negative in the sense that it can stop or influence movement but it can not direct it. Hence, any attempt to improve or sustain the attractiveness of a city must be directed towards providing the framework within which this voluntary process can flourish. The Basic Image expresses the real state of a city's development and consequently it must be a function of those factors which form the foundations for informed voluntary movement for both industries and people. For the sake of continuity of the theoretical exposition however, let me set aside for the time being the practical difficulties involved in rigorously defining and measuring those factors and let me simply say that they include land availability for industrial expansion, access to markets and materials, housing conditions, sanitary and environmental conditions, regional influence etc.

The factors controlling the Basic Image may be further divided into two groups according to whether they express the economic or the social function of the city. The factors of the first group (i.e. land availability, access to markets and materials etc.) properly measured and scaled will give a measure of the true industrial potential of the city; I shall be referring to this measure as the Industrial Indicator of the city. Similarly, the factors of the second group (i.e. housing conditions, sanitary and environmental conditions etc.) will give an estimator of the true social potential of the city; I shall be referring to this measure as its Social Indicator. The representation of the Basic Image of the city as a function of these two Indicators, is not accidental; on the contrary it is consistent with the concept of the city as a socio-economic unit and it is also essential for the analysis and study of its Basic Image. The main advantage of such a representation is that it may be used to underline and, eventually, describe the basic conflict that characterises the development of an industrial city; the conflict between its economic and social functions which has already been discussed in section 3.1 .

3.5 PROPERTIES OF THE BASIC IMAGE

Let me now move a step further and concentrate on the problem of the theoretical shape of the graph of the Basic Image as a function of the two indicators. This is a graph of a function of two variables and it must therefore be a three-dimensional one. In order to get a first feeling of the shape of that graph I start by stating the following simple observations describing the way in which the two indicators operate.

(i) The higher the Industrial Indicator of a city the more Attractive its Basic Image.

(ii) The lower the Social Indicator of a city the less Attractive its Basic Image.

(iii) If the Industrial Indicator of a city is continuously increasing but at the same time its Social Indicator is continuously decreasing, the Basic Image of the city may be either Attractive or Repulsive and sudden changes in its state may be expected.

Observations (i) and (ii) describe the effects of the two indicators when they act separately and independently of each other; observation (iii) on the other hand, describes certain effects which may be expected when both indicators are acting together. Such observations although trivial and only a first approximation of the truth they nevertheless give us some useful background information and help us deduce the shape of the three-dimensional graph. Observation (iii) is the most interesting because it implies that the graph I want to draw is discontinuous. This observation together with the fact that a continuous graph will implicitly rule out the existence of certain properties, such as hysteresis and divergence, which I consider as fundamental in the process of the shaping of a city's Basic Image makes the idea of a discontinuous graph credible and worth pursuing further.

The general mathematical theory of discontinuous and divergent behaviour from continuous underlying forces is called Catastrophe Theory and a brief introduction to it can be found in Appendix 1. The theory is derived from Topology and is based upon some new theorems in the geometry of many dimensions which classify the ways in which discontinuities may occur in terms of a few archetypal forms, called elementary catastrophes. Although the underlying mathematics are difficult and the proofs of the theorems involved complicated, the elementary catastrophes themselves are relatively easy to understand and can be used profitably even by non-experts in the subject. In the case of three dimensions, for example, it is sufficient to know that a theorem exists giving the qualitative shape of a three--dimensional graph which shows all the possible ways in which a discontinuity may occur. This graph is shown in Figure 3.3 and I shall be referring to it as the cusp catastrophe graph. Returning to the present case my intention is to show that the process of shaping of a city's Basic Image may be modelled in terms of a cusp catastrophe. The first step towards this direction will be to show that at least some of the five invariant properties characterising phenomena that may be described by the cusp catastrophe (i.e. bimodality, sudden transitions, hysteresis, divergence and inaccessibility) are present in our particular case. Figure 3.4 illustrates graphically these five properties. Further details about them are given in Appendix 1.

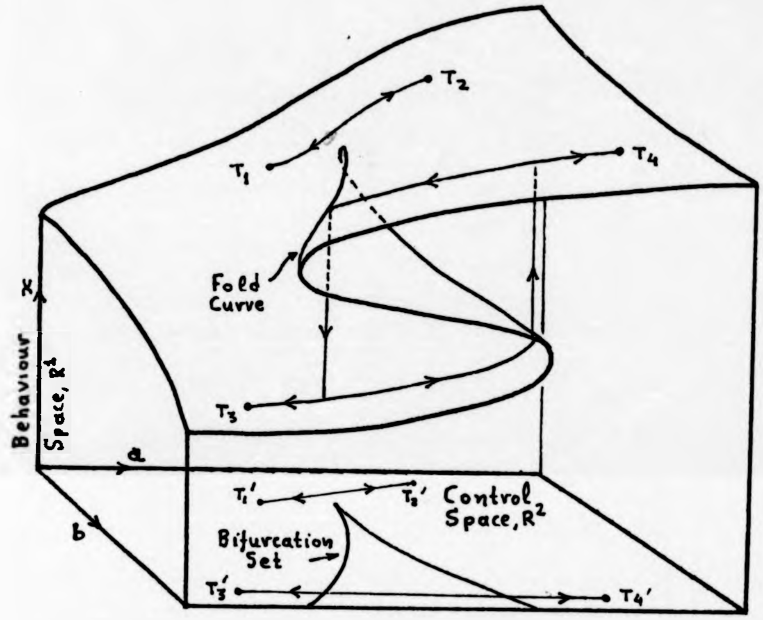

Figure 3.3

The Cusp Catastrophe

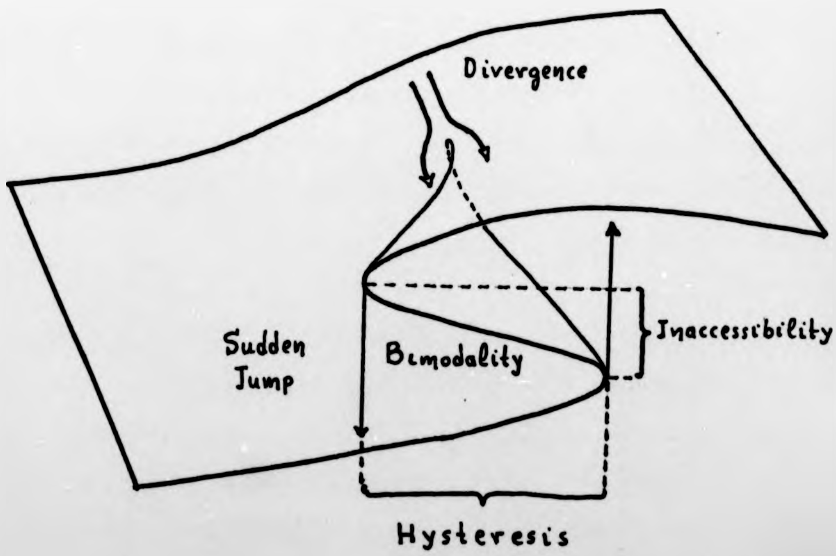

Figure 3.4

Five characteristic properties of the Cusp Catastrophe

The cases of bimodality and sudden transitions from one mode to the other have already been argued extensively and evidence has been presented to support the assumption that those two properties are indeed present in the process of development of an industrial city.

Hysteresis arises in non-linear systems possessing memory. It is a characteristic property of the development of an industrial city and is reflected in the delays observed before any sudden changes in the Basic Image of the city take place. For an attractive city in the process of decline those delays extend its stay on the attractive side and they are due to what I call "locational inertia" or in other words the strong attachment to an area displayed by both industries and people. "Some (industrial) activities" writes F.J. Monkhouse[21] "are maintained in districts where the original reasons for their development are no longer significant, or even no longer exist ... This phenomenon is sometimes referred to as "industrial inertia" or (where growth and expansion have continued for various reasons) as "industrial momentum" ." While the main reasons for the industrial attachment to any area are economic, in the case of people they are essentially psychological. Young men and women are the most likely to move out of a depressed area, "but to the family" as E. Wilkinson[5] writes, "the background of a life-time is an asset not lightly to be sacrificed. In a town where you have always lived, and your father or mother before you, there are always relatives and friends who will give a hand in an emergency. Neighbours will help during sickness. Credit can be got at the local shops to tide over some unexpected bad patch. In a new town, one is a stranger with no one to turn to at a moment of crisis". The strength of those psychological factors has been reflected on the poor results of various Government schemes aiming to transfer unemployed workers and their families from depressed to more prosperous areas. Finally, a Government Survey (Harris and Clausen[6]) found that of workers who thought a suitable job would not be easy to find locally, 45% would rather take a less suitable job in their home area than move elsewhere if they become unemployed. This finding verifies the existence of strong "residential inertia". For a city that has fallen on the repulsive side, the forces of inertia make the return to prosperity very difficult. Economic depression like economic growth is an essentially cumulative process. Once the city has reached a certain stage of its development writes L. Mumford[1] "it needs a terrific exertion of social force to overcome the inertia, to alter the direction of movement". D. Eversley[6] talking about urban decline and the appearance of "urban blight holes" concludes that "the idea that a hole is costless is simply naive. The hole has raw edges, irritant edges and that is why the hole spreads and deepens". Finally, H.Mess[11] writing in 1928 about the decline of industrial Tyneside concludes that "...it was when rates were low that nothing much was done. It would be possible then to accomplish what now is desperately hard to do...".

A process is generally considered as divergent if insignificant changes in the initial stages of its development may result in large differences in later stages (see Figure 3.4). An example of divergence would be the case of two cities that start off from similar initial conditions but experience marginally different public and private inputs which result in one of them remaining attractive while the other declines. Divergence is usually recognisable in the case of two competing cities especially in a period of rationalisation of their main industries. The very different routes of development for many ship-building areas after the reorganisation of the industry in the 1930s underline the presence of divergence. Jarrow, one of the victims of that period, had its shipyards closed not because they were inefficient —on the contrary they were among the six largest and most competitive in the country (Wilkinson[5])— but as the result of a wider rationalisation strategy. The closure of the yards led to Jarrow's eventual decline beyond recovery while at the same time towns of similar stature expanded, by taking full advantage of their increased share of the markets.

A set of values in the co-domain of a given function are generally considered as inaccessible if they are only attainable in an unstable way (see Figure 3.4). In our particular case, inaccessibility means that certain values of the axis measuring the Basic Image of a city may not be attained or rather that they may be attained only very briefly. Those values are around zero representing a neutral city image. The idea of inaccessibility although never expressed in this explicit way, is not novel in Urban Literature. The loss of confidence of the community in the future of a city "leads", according to D. Eversley[6], " to accelerated migration, rapids shifts in investment, and physical neglect". The more sudden the loss of confidence the more rapid the decline. A city in decline enters a vicious circle where problems mount as income from rates shrinks. The blight spreads at an accelerating rate and acts as a negative multiplier reinforcing and speeding up the depression. The acceleration of its decline, once the city has entered the "deprivation cycle", is therefore, beyond doubt and so is the rapidity of its growth, once the city has entered a period of prosperity. The potential of high acceleration in the loss or gain of a city's attraction power once it has entered a cycle of deprivation or prosperity suggests that in such cases a range of values of its Basic Image representing neutrality may be generally considered as unstable and therefore practically unattainable.

Finally, the Dynamic of the model representing the changes in the state of the Basic Image of a city is the desire of the prospective movers to maximise their satisfaction. I have already presented evidence suggesting that a set of minimum criteria must be satisfied if the city is to be considered as a potential final choice by any group of movers. As long as their satisfaction is maximised by moving into (or staying in) the city the Basic Image of the city remains attractive. It becomes repulsive when their satisfaction is maximised by moving (or staying) out.

3.6 THE IMAGE EQUATION

I have presented evidence to support the assumption that all five properties characterising phenomena that may be described by the cusp model are present in the process of development of an industrial city. In this section I shall formalise this thesis by presentng it in a rigorous mathematical way and using the cusp model terminology. The ultimate objective of this exercise is the derivation of the equation that expresses the Basic Image of a city as a function of the Industrial and Social Indicators. I shall be referring to this equation as the Image Equation.

Let $C = R^2$ be the control space with coordinates α and β measuring the Industrial and Social Indicator of a city respectively. Each control point $c = (\alpha, \beta) \in C$ represents a particular combination of those two indicators.

Let also $I = R$ be the behaviour space with coordinate i measuring the Basic Image of a city. Therefore I represents the possible levels of a city's Basic Image ranging from very attractive to less attractive through indifferent to repulsive.

Each control point c determines a particular distribution of the opinion of the set of the prospective movers about the city. I can incorporate the parametrised family of distributions into a single probability function P by defining

$$P : C \times I \longrightarrow R$$

such that

$$P(c,i) = P_c(i)$$

$P_c(i)$ denotes the probability of a city's Basic Image being i given the control point $c = (\alpha, \beta)$

Let M_c denote the set of maxima of P_c. M_c is a function from C to I i.e.

$$M_c : C \longrightarrow I$$

Let also M be the graph of M_c. M is contained in the three-dimensional space $C \times I = R^3$ and is defined by the set of points

$$M = \text{closure}\left\{(c,i);\ c \in C, i \in M_c\right\}$$

My intension is to show that the graph M is qualitatively equivalent to the cusp catastrophe graph shown in Figure 3.4, with

Basic Image $= x$

Industrial Indicator $= \alpha$

Social Indicator $= \beta$

I have so far presented evidence suggesting the strong likelihood of such an equivalence; a complete proof of this equivalence however requires the proof of the following hypotheses.

HYPOTHESIS_1: P is a smooth and generic function. (This hypothesis, however, may be considered as essentially always true since any continuous function can be approximated arbitrarily closely by a smooth generic function).

HYPOTHESIS_2: For a city with fixed Social Indicator and increasing Industrial Indicator, the higher the Industrial Indicator the more attractive its Basic Image.

HYPOTHESIS_3: For a city with moderate or high Social Indicator and high Industrial Indicator the opinion of the prospective movers is unified in considering its Basic Image attractive.

HYPOTHESIS_4: For a city with low Social Indicator and moderate or low Industrial Indicator the opinion of the prospective movers is unified in considering its Basic Image repulsive.

HYPOTHESIS_5: For a city with moderate or low Social Indicator and moderate or high Industrial Indicator the opinion of the potential movers is divided, between those who consider its Basic Image attractive or repulsive depending not only on the present state but also the recent history.

Quantitative terms such as "low", "moderate" and "high" are used in a relative sense. Their respective range of values are not fixed but they depend on the relative weights attached to each of the two indicators in defining the Basic Image of a city. If, for example, the Social Indicator is of little importance only, its value must be extremely high or low in order to have any significant effect on the value of the city's Basic Image. Inopposite case slight deviations of the Social Indicator from its normal value may result into considerable changes in the value of the city's Basic Image.

At this point, one may notice that the hypotheses presented so far do not cover the case of low Industrial Indicator and high Social Indicator. The reason is that such a combination is not characteristic of an industrial city. Aprospering industrial city has obviously a high industrial potential. A declining industrial city, on the other hand has experienced a deterioration of its Industrial Indicator has normally experienced a parallel deterioration of its Social Indicator. The reason is simple; improvement or even maintenance of the level of the Social Indicator requires a considerable expenditure. The income of an industrial city, on the other hand, shrinks as the attraction power decreases and this results to a parallel deterioration of its Social Indicator. The case of low Industrial Indicator but at the same time high Social Indicator is therefore only attainable by a non-industrial city. This may be a historical city, a tourist resort, a university city, or indeed a rural capital; in general a city where the underlying mechanisms of development operate in a different way than that described for the industrial city. If the Industrial Indicator of a non-industrial city, with an already high Social Indicator, starts increasing the city may eventually become an attractive industrial city. Indeed during the last few years the decline of established industrial cities and the seemingly high economic costs for their revival have tempted industries and people to look for alternative locations. This is a potentially dangerous trend and the introduction of certain Government policies which effectively assist it has ignored two crucial facts: (i) the high social costs generated from an unassisted broken community, and (ii) the rapid spread of blight and misery from the disused and abandoned cities to the new "safe" areas.

Returning to the subject of the hypotheses I can say that, since the proposed model concerns the development of industrial cities, the hypotheses presented so far are adequate and cover all the stages of development attainable by an industrial city. For reasons of continuity of the presentation let me set aside for the time being the task of proving those hypotheses and simply accept their validity Details about their proof are given in Chapter 11.

Having accepted the fact that the graph of M_s (Fig. 3.5) is qualitatively equivalent to the cusp catastrophe graph, I can now

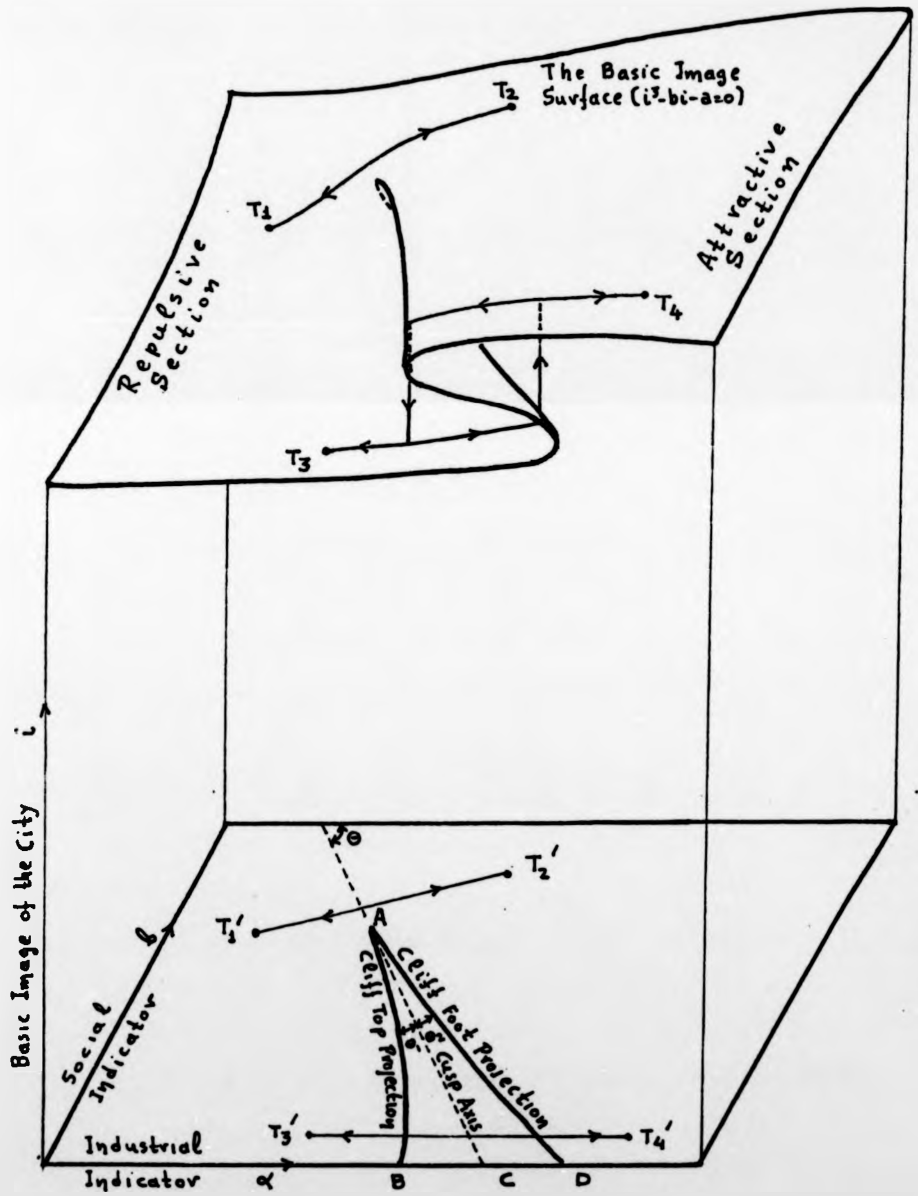

Figure 3.5

The Graph of the Basic Image

say that the value i of the Basic Image of a city at each point in time is given as a solution of the equation

$$(1) \qquad i^3 - bi - a = 0$$

where

$$\left.\begin{aligned} a &= m(\alpha-\alpha_0) + (\beta-\beta_0) \\ b &= (\alpha-\alpha_0) - m(\beta-\beta_0) \end{aligned}\right\} \quad \text{if } m \leqslant 1 \quad (\text{i.e. } \theta \leqslant 45°)$$

and

$$\left.\begin{aligned} a &= (\alpha-\alpha_0) + (1/m)(\beta-\beta_0) \\ b &= (1/m)(\alpha-\alpha_0) - (\beta-\beta_0) \end{aligned}\right\} \quad \text{if } m > 1 \quad (\text{i.e. } \theta > 45°)$$

I shall be referring to equation (1) as the Image Equation Details about its derivation are given in Appendix 1.

The variables α, β as I have mentioned already measure the Industrial Indicator and the Social Indicator of the city respectively. The point (α_0, β_0) corresponds to the vertex of the cusp while $m = \tan\theta$ represents the slope of the cusp axis.

The exact location of the cusp on the control space is discussed in the next section. At this stage I shall consider a fixed position of it as shown in Figure 3.5. AB and AD are the projections on the control space of the cliff top and cliff foot respectively; AC is the projection of the cusp axis. In the present application $\theta_1 = \theta_2 \approx 15°$. The projection of the cliff top ($\theta_1 \approx 15°$ to the left of the cusp axis) represents the locus of breaking points for cities undergoing sudden loss of attractiveness. The projection of the cliff foot ($\theta_2 \approx 15°$ to the right of the cusp axis) corresponds to the set of turning points for cities going through a sudden transition from decline to prosperity. Typical trajectories on the behaviour space and their projections on the control space are also shown.

3.7 CHANGES IN THE POSITION OF THE CUSP

I have so far presented evidence to support the assumption that the graph of the Basic Image of a city is qualitatively equivalent to the cusp catastrophe graph. My next step will be to define the position of the cusp on the control space. In general, the position of the cusp depends on the position of the vertex (α_o, β_o) and the slope $m = \tan\theta$ of its axis. In the present case α_o, β_o represent the value of the two indicators for a hypothetical city which is taken to represent the average of all cities of the country to which the city under study belongs. I shall be referring to this city as the "Normal" city. Further details about the values of α_o, β_o as well as about the concept of the normal city will be given in chapter 6. At this point, however, I can say that the values of α_o, β_o, as defined for the purposes of the model, may be generally considered as independent of time and indeed constant over the period covered by the model. The same however, cannot be said for the value m of the cusp axis slope. In this particular case, m expresses the relative importance of the two indicators in determining the Basic Image of a city, and empirical evidence suggests that the weights attached to each one of them change over time. More precisely, during the early stages of a country's development Industrial Indicator is by far the dominant factor in determining the Basic Image of a city, while in later stages, the relative importance of the Social Indicator is gradually increasing; in other words the value of m increases as the industrialisation and development of a country progresses. An analysis of the causes behind the changes in the value of m for the case of England will be attempted in chapter 5 and various ways of modelling them will be discussed.

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PART II

Presentation of the Model

Chapter 4

Introduction to the Proposed Model

Having defined the concepts of Basic and Specific Image of a city I shall now go on to introduce the proposed model. The first two sections of this chapter are devoted to its conceptual structure and the analysis of the main urban entities involved in it; the third section covers its technical structure and particularly the form of equations used and the computation process; finally the last section discusses briefly matters of presentation.

4.1 CONCEPTUAL STRUCTURE

The proposed model is designed to simulate the process of changes and development of an industrial city over a period of time. Its primary objective is to help the understanding of the mechanisms which govern the structure and behaviour of a given city, inother words it is primarily a dynamic descriptive model. Its structure, however, allows for possible extensions of its use as a predictive or planning model and chapter 10 discusses those extensions and the means of implementing them.

The proposed model may be divided into four submodels.

The first submodel generates the effect of exogenous changes on the coefficients of the Image Equation and hence on the position of the cusp on the control space. The second simulates the process of derivation of the Basic Image of a given city. The value of the Basic Image serves as input to the third submodel which in turn generates Specific Images of the given city as perceived by the various groups of potential movers. The values of the Specific Images serve as input to thefourth submodel which then goes on to simulate the changes of stocks of the various urban entities over the next time period.

Spatial distribution of urban entities lies outside the main objectives of the present thesis. In view of this and in view of severe time limitations the process of location has not been included in the proposed model. A fifth submodel, however, may be easily added so as to cover this process. Chapter 9 presents a brief analysis of the location process together with broad guidelines for its modelling. It also discusses the necessary steps for its eventual inclusion in the proposed model.

At the end of each simulation run, the model produces an "information sheet" giving details of the current state of the various urban entities. I shall be referring to that "information sheet" as the "Description of the city".

Schematically, the five submodels of the complete model and their interconnection are shown in Figure 4.1. Note that the fifth submodel dealing with the spatial distribution lies outside the main closed loop and it is treated as an appendage.

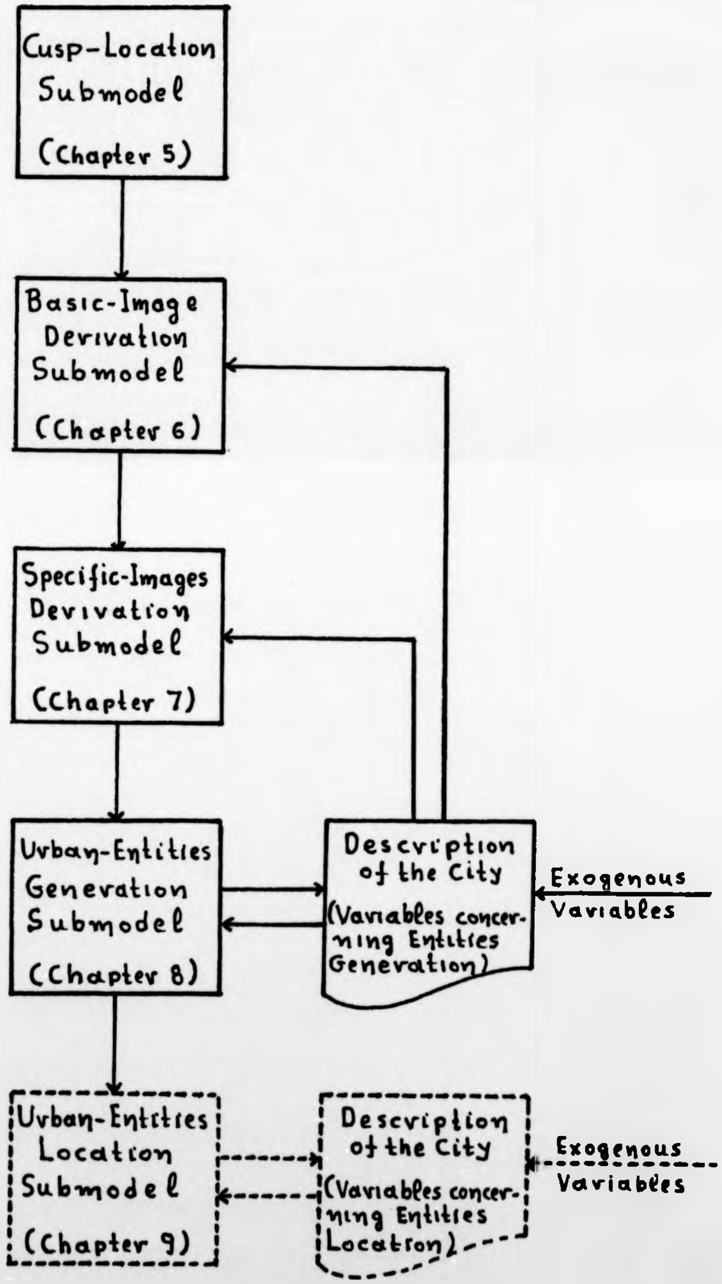


Figure 4.1

Outline of the Proposed Model

If the user of the model feels that any relative changes in the coefficients of the Image Equation may be of only marginal significance for the kind of application with which he is dealing, he may simply ignore the first section of the model. This simplified version may prove very useful in a case where a model of a city is needed to cover a period of time during which the chances of any significant changes in the coefficients of the Image Equation are very slim.

4.2 URBAN ENTITIES

The main entities of an urban system may be, generally, classified under the following four groups (Ref[1]).

People

Activities

Infrastructure

Land

The model includes entities belonging to all four groups and in the next few pages I shall briefly introduce the most important of them. An alphabetical list of all entities used in the model with their definition is given in Appendix 6

4.2.1 People

People are grouped in various ways. The first classification is according to their status in the family and two groups are distinguished:

Heads of family

Non-Heads

The term "Head of family" denotes the main wage-earner and the model implicitly assumes that he is,in any case,the husband. Heads are further subdivided into the following groups:

Economically Active

Retired

The process of retirement is explicitly modelled.
Non-Heads are subdivided into the following groups:

Economically Active

Eligible but not available for work

Under school leaving age

Over retirement age

The Economically Active Non-Heads together with the Economically Active Heads constitute the Total Economically Active population in the city. Economically Active persons may be either Employed or Unemployed. However, both Employed and Unemployed are classified according to their professional qualifications into three groups:

Professional

Skilled (both manual and non-manual)

Unskilled

The model assumes that Economically Active persons may be promoted or relegated to the next occupational group and the process of occupational mobility is explicitly modelled.

The groupings I have described so far are summarised in Figure 4.2.

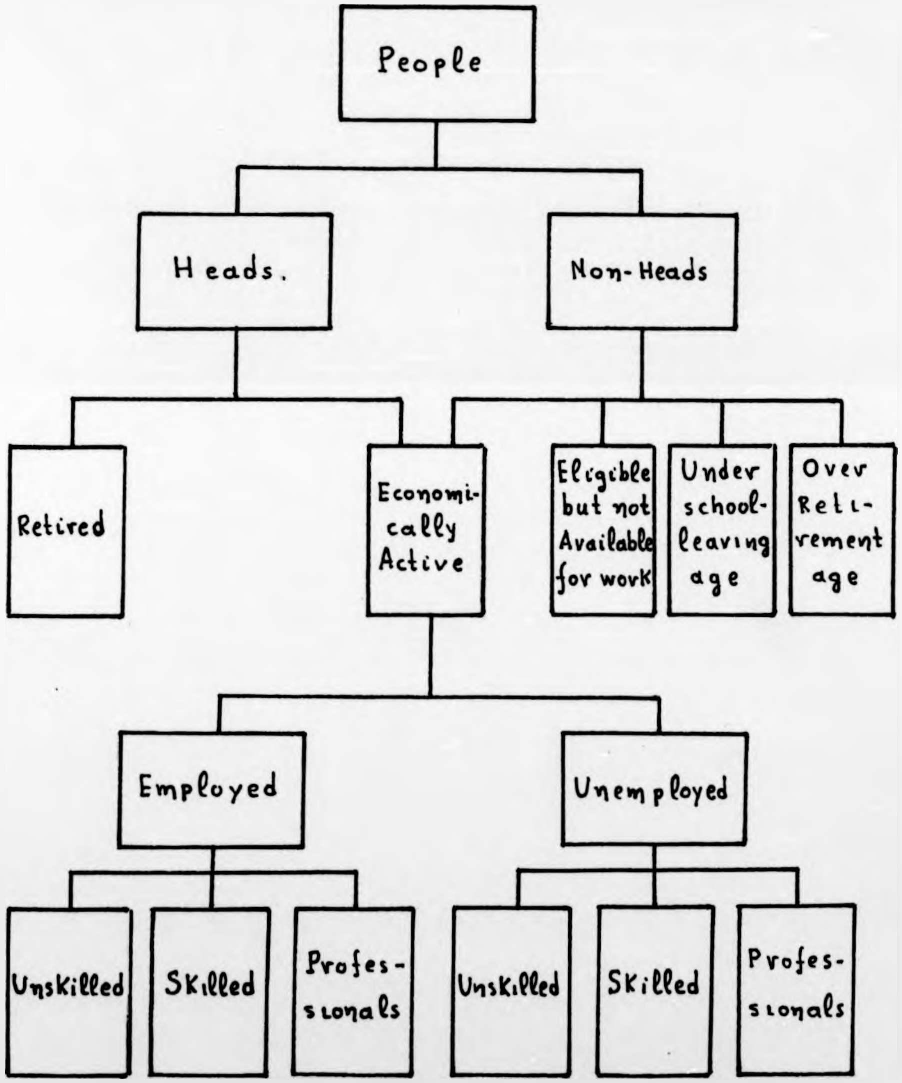


Figure 4.2

Groupings of People

The next grouping concerns Heads of families only. They are classified according to their income level and the following three groups are distinguished (Figure 4.3):

High-Income Heads

Medium-Income Heads

Low-Income Heads

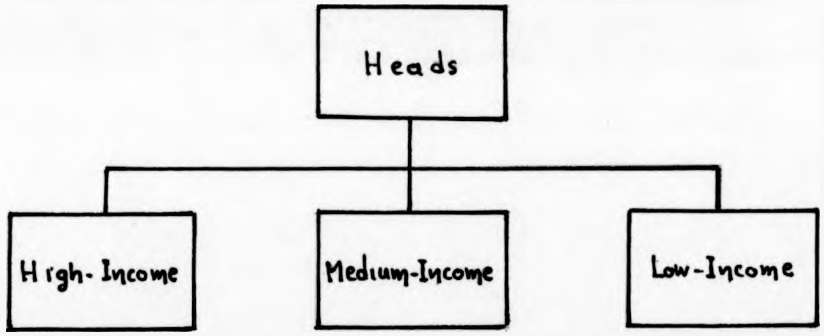


Figure 4.3

Classification of Family Heads

In the case of a short time-horizon application the income brackets for those groups may be defined exactly. In the case of a long time-horizon application however, any definition of those income-brackets has little or no meaning; in such a case the three income groups will be simply taken to represent, in an unquantified way, Heads of families with income in the high, medium or low section of the relevant income scale respectively.

The two-way grouping of Heads according to both their occupation and economic status is considered essential because their employment prospects depend on their professional qualifications but on the other hand their choice of housing type and location depends ontheir income level. In the present case Heads of families are initially classified according to their occupational status. Although a detailed skill-income conversion method may be generally used to reclassify them according to income level for the purposes of the model and for reasons of simplification the following assumptions have been made:

(i) All Professional Heads,apart from those prepared to accept Unskilled Jobs,belong to the High Income group.

(ii) All Skilled Heads,except from those prepared to accept Unskilled Jobs,belong tothe Medium Income group.

(iii) All Heads occupied in Unskilled Jobs, those out of work and all the Retired ones belong to the Low Income group.

Finally, let me refer to the composition of the family unit. The proposed model assumes that the entire city population belongs to family units and distinguishes between two types of them; families under Active Heads and families under Retired Heads. It further assumes that all members of a family of the former type are under the retirement age while all the members of a family of the latter type are over the retirement age and hence inelligible for employment.

4.2.2 <u>Activities</u>

In the proposed model the following two activities are explicitly represented

Residential Activity

Industrial Activity

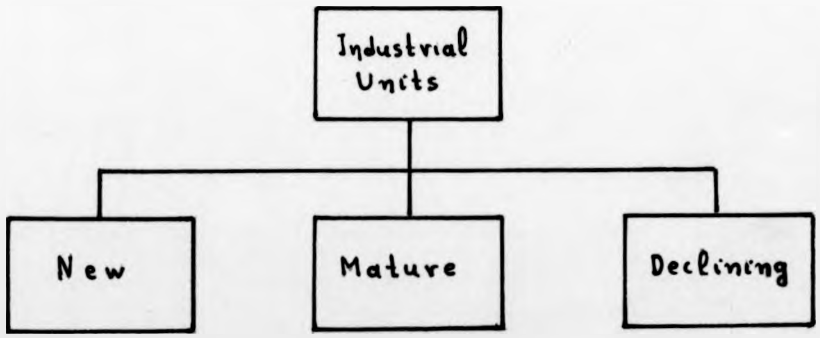
Families, or rather Heads of families, classified according to their income level are the genarators of residential activity. Their classification has already been presented in the previous section.

Industrial Units are the generators of industrial activity. For the purposes of the model an Industrial Unit has been defined as a group of individuals which are technically equipped and possess a variety of skills; therefore, they can function effectively and generate industrial activity. Industrial Units are classified according to their stage of development, and consequently according to the degree of activity they can generate, into the following three groups (Figure 4.4):

New Industrial Units

Mature Industrial Units

Declining Industrial Units



<u>Figure 4.4</u>

Classification of Industrial Units

Industrial Units belonging to any of the three groups may decline as a result of ageing and move into the lower group or cease

operation. The process of decline is explicitly modelled.

Construction activity is generated outside the Industrial Units and it is also explicitly modelled. Finally, no explicit distinction has been made between manufacturing and non-manufacturing (or service) activity; however, the changing nature of industrial activity and the increasing importance of the non-manufacturing sector have been implicitly taken into account in many ways, as it will become clear in the course of the model's presentation. Furthermore the model may be easily extended so as to include an explicit distinction between manufacturing and non-manufacturing activity if such a distinction is essential for a certain application.

4.2.3 Infrastructure

Two types of infrastructure are explicitly involved in the proposed model; Housing Units and Industrial Buildings. Transportation networks although may implicitly be taken into account in certain cases, such as the determination of the Accessibility Index they are not explicitly represented.

Let me start with the Housing Units. The model allows for Housing Units to be constructed by both the Private and the Public Sectors. Housing Units available in the city at each point in time may be classified in various ways. The first classification is according to their physical condition and the following two groups are distinguished.

Housing Units Fit for Occupation

Housing Units Unfit for Occupation (or Slums)

The second classification concerns only Housing Units Fit for occupation and is according to their cost. In this case the following three groups are distinguished:

High-Cost Housing Units

Medium-Cost Housing Units

Low-Cost Housing Units

As in the case of income brackets the cost brackets for those three groups of Housing Units may also be defined exactly, provided that the time-horizon of the particular application is short. In the case of a long time-horizon application however, those three groups of Housing Units will be simply taken to represent, in an unquantified way, houses in the upper, middle or lower part of the relevant housing cost scale respectively.

As I have mentioned already, the Heads of families choose Housing Units for them and their families on the basis of their income level. Under normal conditions the occupants of those three groups of houses will be families under High-Income, Medium-Income and Low-Income Heads respectively. In cases of housing shortage however, the model assumes that Heads of higher income have priority in any type of Housing Units over Heads of lower income. Furthermore families under Low-Income Heads may be accommodated in Unfit Housing Units.

Finally, the model assumes that Houses belonging to any of the three groups may physically decline and move to the lower group. The decline of Low-Cost Housing Units relegates them into Houses Unfit for occupation. The processes of construction, decline and demolition of Housing Units are explicitly modelled.

The various groupings of Housing Units are summarised in Figure 4.5.

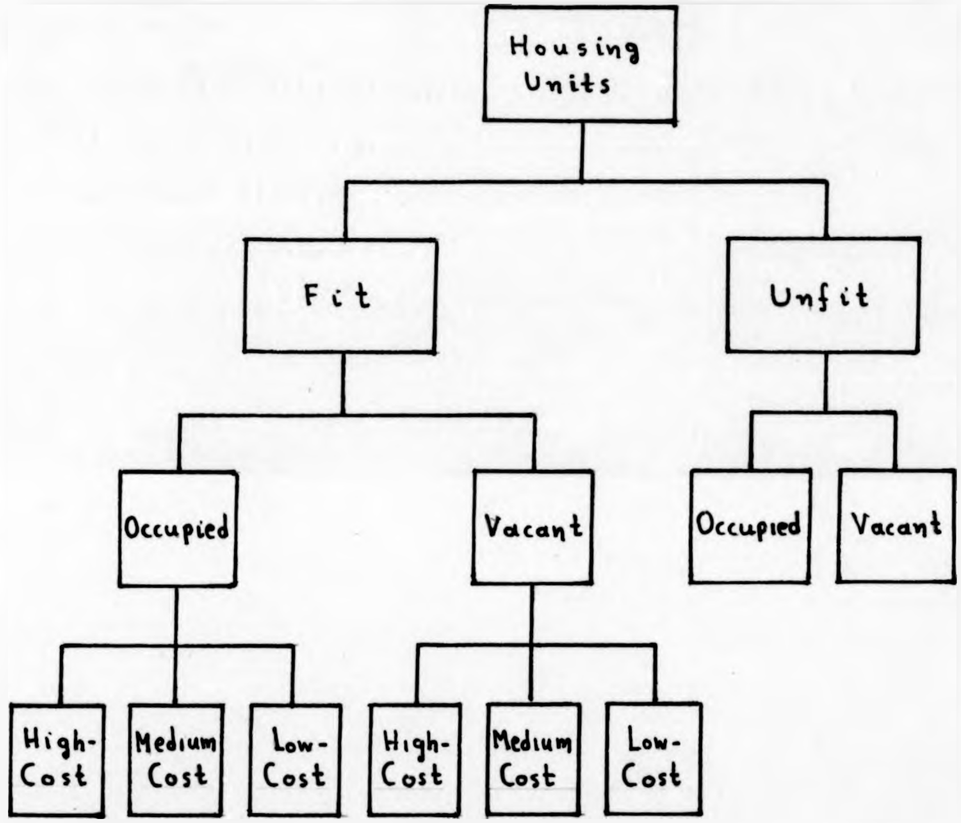


Figure 4.5

Classification of Housing Units

Industrial Buildings are classified in the following two groups:

Industrial Buildings Fit for Occupation

Industrial Buildings Unfit for Occupation

Every Industrial Building belonging to the first group may be either occupied by an Industrial Unit of any of the three types mentioned in the previous section, or vacant. Furthermore, Industrial Buildings Fit for occupation may physically decline and become Unfit. The processes of construction, ageing and demolition of Industrial Buildings are explicitly modelled. The various groupings of Industrial Buildings are summarised in Figure 4.6.

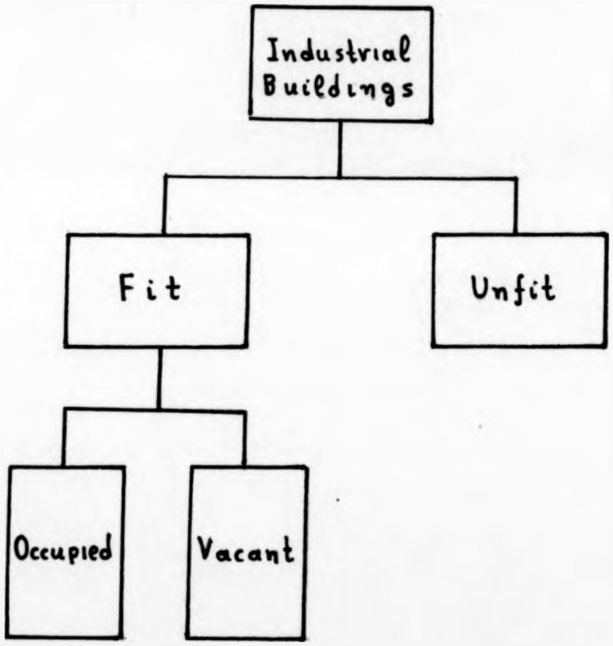


Figure 4.6

Classification of Industrial Buildings

4.2.4 Land

Land is an entity that may be treated in various ways. If the city area is considered as fixed then land is a variable of critical importance. If on the other hand, the city area is allowed to expand in order to accommodate further growth the importance of the land is somehow diminished, but nevertheless it remains a basic entity regarding the provision of infrastructure. For the purposes of the model the latter approach has been used.

Land is occupied by both Housing Units and Industrial Buildings. Furthermore, the occupied land may be distinguished into the following two groups:

Usefully Occupied Land

Derelict Land

Obviously the first group covers the area containing Housing Units and Industrial Buildings fit for occupation. Similarly, the second group covers the area containing Housing Units and Industrial Buildings unfit for occupation. The process of land clearance is explicitly modelled. The various land uses are summarised if Figure 4.7.

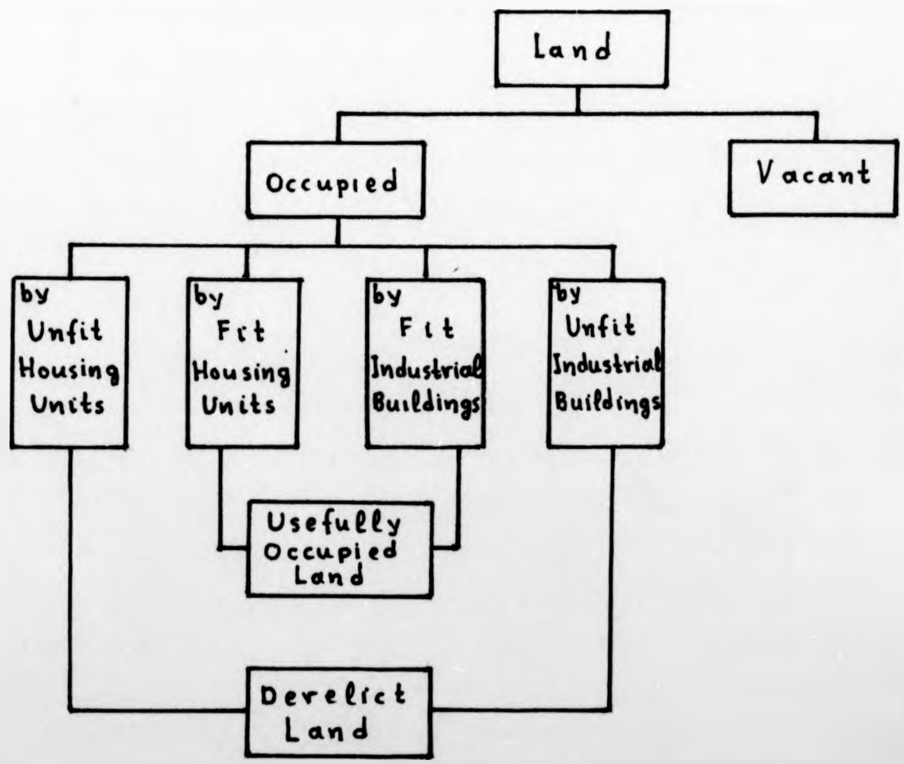


__Figure 4.7__

Land Uses

4.3 TECHNICAL STRUCTURE

The model is expressed as a set of difference equations which simulate the development of a given city over a period of time. The computer programming language used to process the simulation is DYNAMO . However certain mathematical algorithms have been written in ALGOL and a special technique has been used in order to link the ALGOL procedures with the main DYNAMO program.

Since DYNAMO (DYNAmic MOdelling) is a special-purpose compiler ,for generating the running code to simulate the behaviour of dynamic feedback systems,it is thought that a brief introduction to the way it operates would facilitate the understanding of the model to be presented. Such an introduction with special emphasis on those features of the compiler that will be frequently appearing in the next few chapters is presented below. Reasons for the choice of DYNAMO as the programming language in the present case are also given (Pugh[2],Burroughs[3]).

4.3.1 Equations

DYNAMO has been designed for problem oriented non-programmers. It treats time as sequence of intervals with a constant length DT. When computing the successive time steps in the dynamic behaviour of the given systemthe following notation is used.

The letter K designates the point in time where the current computation applies. Correspondingly J marks the point where the preceding computation was made and finally L denotes the next point in time. The interval between times J and K is called the JK-interval and similarly the interval between times K and L is called the KL-interval. This time convention is the key to classifying DYNAMO equations by functional type. A DYNAMO equation has the following general form:

<QUANTITY NAME = EXPRESSION>

The right-hand side consists of quantity names —chosen by the modeller— and arithmetic operations. Quantities with single subscript (i.e. Q.J) are called levels while quantities with double subscript (i.e. Q.JK) are called rates. DYNAMO equations may be classified into the following 6 types:

Level Equations	(L)
Rate Equations	(R)
Auxiliary Equations	(A)
Supplementary Equations	(S)
Initial Value Equations	(N)
Constant Equations	(C)

A level equation relates a quantity at the current time to its last value and to its rates of change during the interval between calculations. Mathematically it indicates integration. The format of a typical level equation has as follows:

$$L.K = L.J + (DT)(RA.JK - RS.JK)$$

where

L.K :the new value of level L at time K.

L.J :the value of level L at the previous time J.

DT :the length of the solution interval between time J and K.

RA.JK :the rate added to level L during the JK interval.

RS.JK :the rate substracted from level L during the JK interval.

At the start of the computation an initial value L for every level is required .

A rate equation expresses how the flows within the system are controlled. The format of a typical rate equation has as follows:

R.KL = f(CONSTANTS AND LEVELS AT TIME K AND RATES FOR THE INTERVAL JK)

where the function f determines the rate R during the time interval KL.

An auxiliary equation is a simple algebraic function of levels and other auxiliary variables at the same point in time. Very often the meaning of a rate equation can be clarified if this equation is divided into parts which are in turn written as auxiliary equations. The format of a typical auxiliary eqûation has as follows:

A.K = f(LEVELS AND AUXILIARY VARIABLES AT THE SAME POINT IN TIME)

A supplementary equation is a type of auxiliary equation. Its only distinctive feature is that it is computed only to provide output.

As I have mentioned already an initial value for every level equation is required at the start of the computation. Every one of those initial values is given by an initial value equation. The format of a typical initial value equation has as follows:

N = f(CONSTANTS)

A constant equation is very similar to an initial value equation. The only difference is that its right hand side is restricted to a numerical value i.e.

C = NUMERICAL VALUE

Although the modeller may place equations in any order that is easy or meaningful to him, DYNAMO evaluates them, in each DT-loop, in the following order:

Level Equations

Auxiliary Equations

Rate Equations

Supplementary Equations

Within each equation type, DYNAMO determines a suborder that evaluates variables on the left-hand side before they are used on the right hand side of any equation.

4.3.2 Functions

A function is a convenient way to relate several values. The form of the relationship is not expressed explicitly but understood from the name of the function. A number of functions are built into DYNAMO. A function may be used on the right of the equal sign and the proper number of arguments (inputs to the function) must be provided in the right order. A DYNAMO function has the following general form:

$\langle$VALUE$\rangle$= NAME OF FUNCTION(ARGUMENTS)

Functions that have been used in the construction of the proposed model are:

EXPONENTIAL Function

LOGARITHMIC Function

SQUARE ROOT Function

SAMPLE Function

STEP Function

MINIMUM Function

MAXIMUM Function

CLIP Function

SWITCH Function

TABLE Function

The first three are computational functions and have their normal algebraic sense. Their formats are

EXP(A) , LOGN(A) , SQRT(A)

respectively where A may be level, auxiliary or constant quantity. The next two are logic time-triggered functions.

The SAMPLE function

<VALUE> = SAMPLE(P,INTERVAL)

is useful for modelling periodic or time-irregular constants, or variable input to decision making process. It is set equal to the current value of P, at sample times separated by intervals of length INTERVAL, and retains this value until the next such sample time. An initial value of the function may be provided if required.

The STEP function

<VALUE> = STEP(P,T)

has the effect of a gate that opens after time T allowing STEP to equal P. The value of the function remains zero until the step time T i.e.

<VALUE> = 0 if TIME T

<VALUE> = P if TIME ≥ T

The remaining five are logic value-selection functions.

The MINIMUM function

<VALUE> = MIN(P,Q)

selects the lesser of two inputs P,Q .

Similarly the MAXIMUM function

<VALUE> = MAX(P,Q)

selects the greater of two values.

The CLIP function

<VALUE> = CLIP(P,Q,R,S)

makes a choice between two quntities P and Q on the basis of the relative values of the quantities R,S i.e.

<VALUE> = P if $R \geq S$

<VALUE> = Q if $R < S$

The quantities P,Q,R,S need not be distinct.

The SWITCH function

<VALUE> = SWITCH(P,Q,R)

is used for testing two decision rules. This may be done either dynamically, during a run, or statically, during a rerun, by assigning a different value to R. For example:

<VALUE> = P if $R = 0$

<VALUE> = Q if $R \neq 0$

Finally, a DYNAMO user may need to describe a rather arbitrary relationship between two variables. Frequently, this relationship can be described more easily by a graph or a table corresponding to the graph. The TABLE function expresses such a relationship. It requires two equations. The first, known as the Table equation, has the following format:

$$TNAME* = E_1/E_2/.../E_N$$

As we can see, it consists of an array of numerical values that provide the points upon which the second equation, known as the Table look-up function, operates. The format of a typical look-up function has as follows:

$$\langle \text{VALUE} \rangle = \text{TABLE}(\text{TNAME}, \text{P.K}, N_1, N_2, N_3)$$

where

TNAME : the name of the table on which the function is to operate.

P : the input variable for which the corresponding table entry is to be located.

N_1 : the value of P at which the first table entry (E_1) is recorded.

N_2 : the value of P for the last table entry.

N_3 : the fixed interval in P between table entries.

The input variable, P, of a TABLE must be a level or an auxiliary variable. Figure 4.8 illustrates the TABLE function.

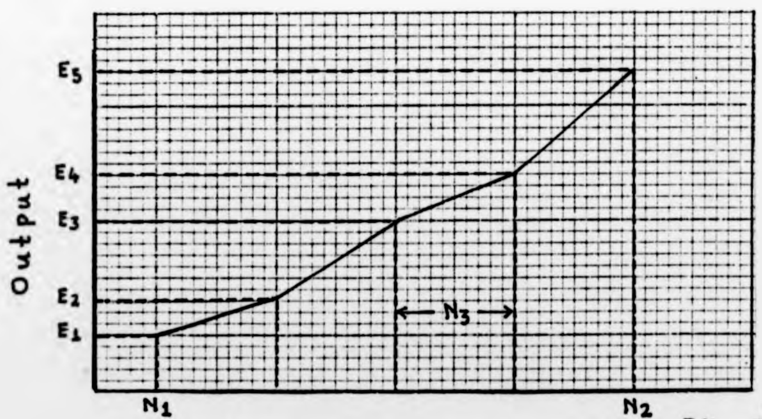


Figure 4.8

Illustration of the TABLE function

As we can see, the TABLE function assumes linear segments between the specified points and finds the output corresponding to any value of P within the range N_1, N_2. If $P > N_2$ or $P < N_1$ then an error comment is given. An input variable with a wide range of values may be substituted by its logarithm; in this way the expressed relationship becomes easier to handle but it otherwise remains unchanged.

An extension of the TABLE function is the TABHL function. The only difference is that the TABHL function does not assume error when $P > N_2$ or $P < N_1$ but instead the last value in the table is extended. The TABHL function is structurally similar to TABLE and it is written as

$$\langle \text{VALUE} \rangle = \text{TABHL}(\text{TNAME}, \text{P.K}, N_1, N_2, N_3)$$

4.3.3 <u>Reasons for Choosing DYNAMO</u>

The choice of DYNAMO as the programming language was based on the fact that it possesses certain properties which facilitate the construction of large simulation models such as the one under consideration. The most important of those properties are discussed below:

(i) Equations may be placed in any order. This is DYNAMO's greatest advantage because it allows the modeller to work with a set of equations arranged in an order meaningful to him but not necessarily the one followed by the compiler for their evaluation. A model presented in such a way is also obviously better understood by the reader.

(ii) DYNAMO is designed to be understood by the novice and the mechanics of using it are very simple. Both tabular and plotted output are available and they can be specified very easily.

(iii) The error analysis is thorough. DYNAMO checks for improper details in equation structure, card punching errors representing impossible situations and also for logical errors that represent inconsistencies within the set of equations; error messages are expressed in easily understood user's terms.

4.4 PRESENTATION

For a better presentation the model has been divided into several parts (i.e. submodels, sectors and sections) which will be analysed over the next four chapters. The division has been done on the basis of the main entity or activity involved in each one of them. Every part normally contains a graphical illustration of the process involved, the set of equations generating it, and brief explanatory comments. The terms appearing in each part are defined in Appendix 3. It is thought that having the set of equations and the corresponding alphabetical list of terms in constant view on two different pages, helps the reader considerably by preserving the continuity of exposition and reducing the amount of searching and page changing. A term used in more than one part is defined in all cases; however, the number of the equation where it is originally defined is also given.

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2. PUGH, A.L. *DYNAMO User's Manual.* The MIT Press, Massachusetts, 1970 (reprinted 1976).

3. BURROUGHS *DYNAMO Reference Manual*, Burroughs Corporation, Detroit, Michigan, 1972 (reprinted 1975).

Chapter 5

Cusp-Location Submodel

Evidence presented in Chapter 3 suggests that the graph of the Basic Image for a given city is qualitatively equivalent to the cusp catastrophe graph and also that the position of the cusp on the control space changes over time. In this particular case, the position of the cusp depends on the slope, m, of its axis. The slope represents the relative weight of each one of the two indicators, Industrial and Social, in defining the Basic Image of a city and its value decreases as the Social Indicator becomes more important. Although the precise form of those two indicators has not been defined yet, it is known that the former measures the industrial potential and economic profitability for the given city while the latter measures its rather more intangible environmental qualities. Consequently, m may in final analysis be considered as expressing the relative influence on the development of a city of factors controlling its economic viability and efficiency as compared to that of factors controlling the quality of life. Obviously, changes in the value of m are to a great extent due to the general shift in the focus of society "from supply to demand, from problems of production to problems of consumption and of welfare in the widest sense" (Rostow[1]). During the early stages of a country's industrialisation "those elements in...the individualist-utilitarian creed which do not lead to a maximisation of output are relatively suppressed", As

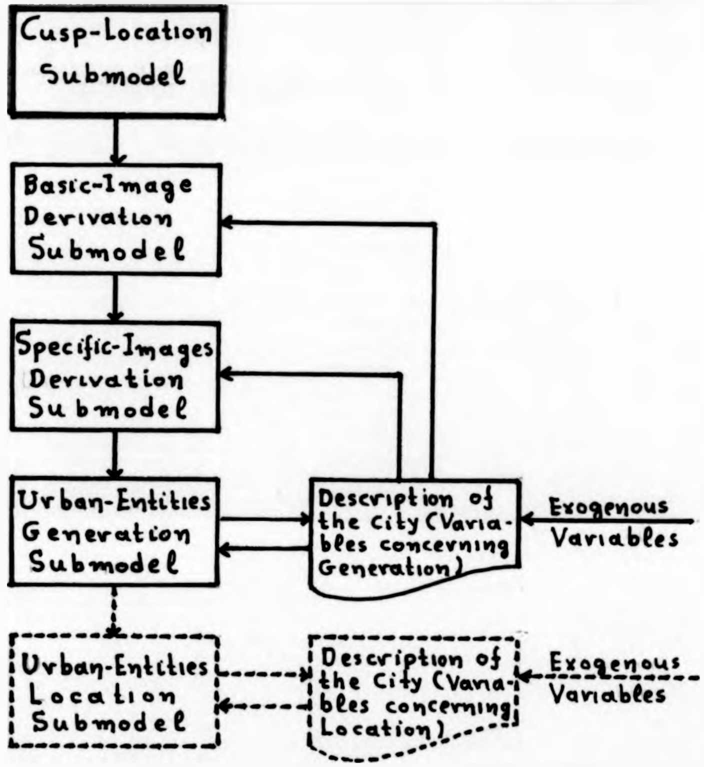

Figure 5.1 Cusp-Location submodel as part of the complete model.

the country approaches a stage of maturity, however, "these more human objectives assert themselves with increased force. Men are prepared in a sense to take risks with the level of output and the incentives in the private sector in order to cushion the hardships of the trade-cycle; in order to increase social security; in order to redistribute income; in order to shorten the working day; and generally to soften the hardness of a society hitherto geared primarily to maximising industrial output (Rostow[1]). My objective in this chapter is to model the movement of the cusp for the case of Britain over the period 1800-1970. The Chapter is divided into four sections. The first discusses briefly changes in major aspects of social policy in Britain over the period covered by the model; the second attempts quantification of those social changes and introduces a relevant measure; the third section relates the general social changes to changes in the slope, m , of the cusp axis. Finally, the fourth section models the changes of m over time. Figure 5.1 relates the cusp location submodel with the rest of the model.

5.1 CHANGES OF SOCIAL POLICY IN BRITAIN

The period 1800-1970 saw a series of fundamental changes which transformed Britain politically and socially. Changes of social policy is the subject of discussion in this section. (Bruce[2], Bruce[3], Gayler et al[4], Harris[5], Parker at al[6], Smales[7]).

5.1.1 Welfare

During the Middle Ages help to the needy was given by their family, the church and the guilds. The growing economic and social stresses of the Tudor times, however, underlined the need for an improved system of poor relief. This was embodied in the Elizabethan Poor Law Act of 1601 by which (i) Parishes were to provide work for the unemployed; (ii) Children of poor families were to be apprenticed; (iii) Relief was to be given to those unable to work; (iv) Persons unwilling to work were to be harshly punished.

Originally the poor were given help in their own houses ("outdoor relief"), and there was no attempt to force them into any kind of institution. Towards the end of the 17th century, however, several attempts were made to meet the cost of poor relief by "setting the poor on work" in workhouses and an Act towards this effect was passed in 1723. The Elizabethan Poor Law provided no real solution to the problem of poverty and unemployment and certainly there was no central fund of money provided by the Government.

With the onset of Industrial Revolution and the fundamental changes in the structure of society, it became clear that private charity could no longer provide even a skeletal welfare serce. The Gilbert Act of 1782 which autherised groups of parishes to form poor law unions had little effct and the Speenhamland System (1795), which made wages up to a minimum subsistence level, met strong opposition amongst the rate payers. The severity of the problem and the growing dissatisfaction of the people led to the Government setting up a Poor Law Commission to investigate it. The Commission recommended fundamental changes which were based upon two principles:

(i) The principle of the workhouse test; relief was to be given only in the workhouses.

(ii) The principle of less eligibility; the position of persons receiving relief in the workhouse was to be less desirable than that of the poorest worker outside the workhouse.

The Government accepted those principles and passed the Poor Law Amendment Act of 1834, which set up a system of poor relief that remained more or less intact until the early years of the 20th century. The Act of 1834 did not deal with the causes of poverty but merely improved the administration machinery for the granting of relief. A scientific investigation into the problem of poverty was not made until 1905, when a new Royal Commission was set up to enquire into it. There was a strong disagreement among the members of the Commissionand as a result two reports were produced. The most significant conclusion of those reports and indeed the turning point in social policy, was the recognition that poverty was a product of social conditions rather than personal failure, and that the state should concern itself with discovering and eliminating its causes. The period 1906-1914saw many changes like the introduction of compensation for injuries received at work (1906), the setting up of Labour Exchanges throughout the country (1909), the fixing of minimum wages in some of the worst paid industries (1909)and finally the provision for health and unemployment insurance in certain trades(1911).

By 1914 the basis of the welfare state had been laid. The inter-war period was characterised by severe financial restrictions but nevertheless the progress of social reform continued. The Insurance Scheme of 1911 was extended to cover all industries and commercial workers (1920) and finally agricultural and domestic workers (1936). Attempts to deal with problems relating to particular areas were also made and two special Areas Acts were passed, aiming to revive the economic activity in Scotland, South Wales, West Cumberland and Tyneside.

In the years that followed the Second World War the foundations of the Welfare State were consolidated. Already a blue-print for future welfare services was in existence. This blue-print has been provided by the Beveridge Report of 1942 which proposed a national minimum of social security for everyone. Beveridge's Report was not adopted entirely but it did stamp out a pattern of future development.

Basic security for everyone was provided by the Family Allowances Act, 1946, the National Insurance Act, 1948, (replaced in 1966 by the Supplementary Benefits System) and the National Health Service Act, 1948. Those basic services have subsequently been extended and improved many times. Since 1968 they have been administered by the Department of Health and Social Security and a Secretary of State for the Social Services has been appointed.

5.1.2 <u>Public Health, Housing, Land-Use and Environment</u>

The very rapid growth of towns during the 19th century underlined the need for improvement in the conditions of life. It was soon realised that poverty could not be dealt with effectively by simply changing the system of poor relief; sanitary improvements and Public Health had also to be considered. In 1842 E. Chadwick, the first Secretary to the Poor Law Commissioners, produced a report exposing the appalling living conditions of the poor. Chadwick's report had a profound effect on the Government and the Public and it eventually resulted in the first Public Health Act of 1848. Under this Act a general Board of Health was established with jurisdiction over the construction of sewers, drains and gasworks, the provision of water and the disposal of refuse. The main limitation of the Act was that it could only come into operation if 10% of the rate-payers required it or if the death rate exceeded 23% per annum. Because of opposition from various groups who wanted to maintain the old system, the Board of Health was abolished in 1858. Two more effective Public Health Acts were passed in 1871 and 1875 which made it compulsory for every area to have a Medical Officer of Health and a Sanitary Inspector.

The Housing problem on the other hand was not really acknowledged in the 19th century. Although certain acts were passed they were rather ineffective and not compulsory. The most important of those was the Act of 1875, which gave Local Authorities the power to pull down slum areas. By 1890 local councils could build their own houses but until some form of financial aid was available from the Central Government very little was done.

The most important pre-war development in the field of Housing and Public Health was the passing of the Housing and Town Planning Act of 1909 which laid down minimum environmental standards; back-to-back housing became illegal under the provisions of this Act. Housing, however, became a very acute problem in the inter-war period. The Private Sector was unable to cope with the increasing demand and the rising cost of land and building materials. Hence the State compelled Local Authorities through the Addison Housing Act of 1919 and other related Acts to survey the housing needs of their area and to provide the necessary ousing with the aid of Government subsidy. At the same time wider environmental issues gained momentum. Successive Acts of Parliament, including the Town and Country Planning Act of 1947 , the Clean Air Act of 1956, the various Distribution of Industry acts, zoning and land use legislation, water management legislation and other measures have established an even increasing legal framework within which efforts are made to improve the "quality of environment". Furthermore a Department of the Environment has been created to direct and co-ordinate the various measures. Slum clearance also received much attention during the 1930's and after 1933 only dwellings to replace slums qualified for Government grants. Slum clearance and renewal continued at an even larger scale after the end of the Second World War.

5.1.3 Education

Public Education was slow to develop in Britain. During the largest part of the 18th century education was very much a privilege. It was available at grammar and public schools for those who could afford it but for the majority of children only a very rudimentary type of education was available by two religious societies, the non-conformist British and Foreign Society and the Anglican National Society.Towards the end of the century the importance of mass education was realised. The rapid growth of population however meant that voluntary organisations were unable to cope and State aid was necessary. Hence the 1870 Education Act compelled

Local Authorities to provide elementary schools where no suitable voluntary schools were available. The attendance in schools became compulsory in 1880 and the minimum school-leaving age was raised in stages until it was fixed —in 1899— at 12 years of age. Elementary education became free in 1891 and a State-provided secondary education was introduced by the Act of 1902.

The most important development of the inter-war period was the passing of the Fisher Education Act of 1918 whose main provision was the raising of the school-leaving age to 14. After the end of the War, the Education Act of 1944 provided for free secondary education for all, the raising of the school-leaving age to 15, and later 16 with compulsory part-time education up to the age of 18, the abolition of fees in state secondary schools and better facilities for the support of University students. Although lack of resources prevented the full implementation of this Act, thechanges in education have indeed been spectacular since the passing of the Education Act of 1890.

5.1.4 <u>Industrial Legislation</u>

During the early stages of industrialisation many manufacturers maintained that the restriction of hours and labour would ruin their trade and put them at a disadvantage with foreign competitors. In the absence of any regulations therefore the heavy concentration of work people into factories and mines led to many abuses and social evils. Efforts at reform were made, but many difficulties stood in the way of early factory legislation and it was not until 1833 when the first effective Act was passed regulating the employment of children in factories. According to this Act:

(i) No child under 9 was to be employed.

(ii) Children between 9 and 13 were not to be employed more than 9 hours a day and were to spend 2 hours at school.

(iii) Children between 13 and 15 were not to be employed for more than 12 hours a day.

An important feature of this Act was that salaried inspectors were to be appointed for the first time whose job was to see that the Law was carried out.

Subsequent Acts followed improving the conditions of labour and in 1847 the "Ten Hours Act" passed which reduced the working hours of women and young persons to 10 a day. At the same period various "Mines Acts" were also passed regulating the conditions of work in mines. The early factory Acts were applicable to textile factories only, but by 1869 they were extended to cover all factories and workshops. During the last part of the 19th century and especially during the 20th century the scope of the factory legislation has been largely extendedand now covers not only the working hours but also the health, the safety, the comfort and the welfare of workers. Such legislation has been presented in the previous sections.

5.2 MEASURING SOCIAL CHANGE

The facts presented in the last four sections indicate clear and indeed very significant changes in all major aspects of social policy in Britain over the last 150 years; my objective in this section is to quantify them. Most of the changes discussed so far were the result of increased involvement and especially financial contribution by the public sector. A measurable quantity which expresses the degree of public involvement in the shaping of social policy, and consequently may be taken to represent changes in all its aspects, is the proportion of the country's GNP which is spent on social services. Table 5.1 — based on information obtained from a paper by J. Veverka[8] — shows the changes in this proportion over the period 1801-1971. Figure 5.2 illustrates them graphically.

TABLE 5.1

GOVERNMENT EXPENDITURE ON SOCIAL SERVICES (U.K)

Year	1801	1811	1821	1831	1841	1851	1861	1871	1881
% of GNP spent on Social Services	1.10	1.05	1.02	1.00	0.99	1.10	1.25	1.38	1.49

Year	1891	1901	1911	1921	1931	1941	1951	1961	1971
% of GNP spent on Social Services	1.60	2.70	3.80	8.10	13.1	15.0	17.2	17.5	17.9

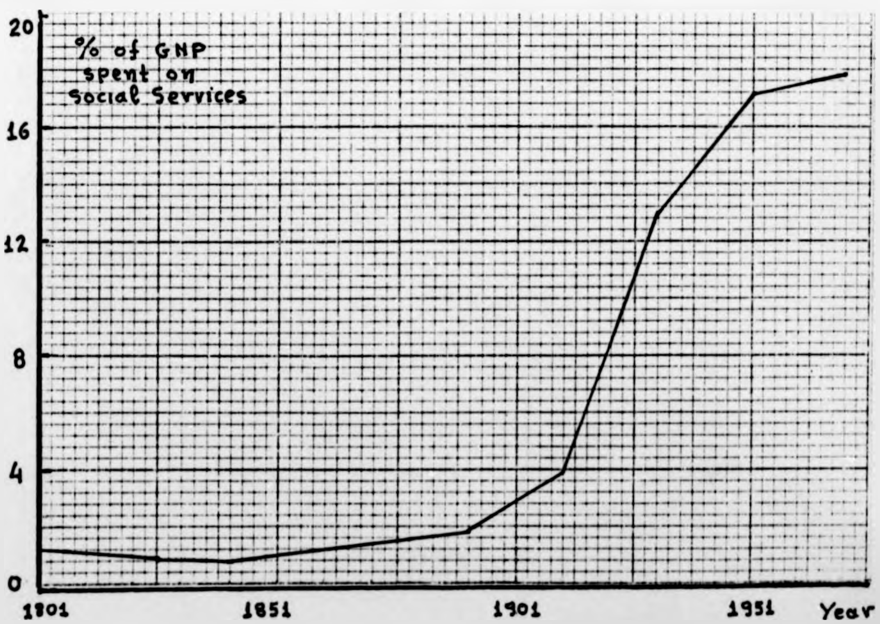

Figure 5.2 Proportion of Britain's GDP spent on Social Services

As we can see, after remaining almost constant for about 80 years, the trend reached a turning point around 1890, when the proportion of GNP spent on social services started increasing significantly. The upward trend continued steeply for the next 70-80 years. The overall trend is in complete agreement with the picture painted in the previous section. The changes experienced in Britain from the last decade of the 19th century ownwards, suggest either a considerable transfer of social responsibility from the private to the public sector (not necessarily accompanied by any proportional social change), or a significant change in social policy initiated by the public sector. The facts presented in the previous sections suggest that in the case of Britain the latter was the case. Therefore the proportion of GNP spent on social services may, in the case of Britain, be taken as an approximate measure of the relative importance placed on the social aspects of the country's development.

5.3 MEASURING CHANGES IN THE SLOPE OF THE CUSP AXIS

I have so far quantified the change in the importance placed on the social aspects of Britains development. My objective in this section is to examine how this change has affected the relationship between the two factors controlling the Basic Image of a city or in other words to quantify the changes in the slope m of the cusp axis.

An increase in the national level of social responsibility and a higher valuation of the social aspects of growth is undoubtedly reflected on the choice of a place to live and work by all potential movers. Their choice, however, is not always free and the effect of national changes concerning social policy on it depends also on the two factors:

Industrial ties to natural resources

Methods of transport

All industries that flourished during the early stages of Industrial Revolution were heavily dependent on natural resources. This fact, in conjunction with the poor state of transport technology, left no choice in idustrial location. Residential location was given little choice also. The remarkable increase in the population coupled with the intensification of the Enclosure Movement and the slump in farming made job search the top priority for every economically active person. In addition the need for very close proximity between residential and work places forced many people to follow industries. Very little, if any, attention was given to the social implications of their decision. The best part of the 19th century saw relatively little social change. However any national changes concerning social policy could not have any significant impact on either industrial or residential location under the conditions described above. The growth of the new industrial cities, which could offer the much needed proximity to materials and power sources, was phenomenal but at the same time its social consequences were very severe. Social surveys of the time revealed the extent of the problem. C.Booth[9] published his book on "The Life and Labour of the People of London" in 1889, and S. Rowntree[10] published his investigation of "York, Poverty, a Study of Town Life" in 1901. Their main findings were strikingly similar and very alarming; over 30% of the population of London and 28% of the population of York, a typical provincial industrial city, lived in poverty. On the basis of this evidence the assumption that ten millions of the country's population, mainly situated in cities, had to endure the torture of living without the bare essentials of life is probably an underestimate of the true situation.

With the turn of the century, however, the situation started changing. The resource-oriented industries began losing their share of the market in favour of "footloose" industries; at the same time, great improvements in transportation methods made movement of goods and people easier and the locational choice much wider. Under those conditions the national changes concerning social policy and the resulting higher aspirations of people, who until then had accepted as a matter of course a very low standard of living, could and indeed did start to inluence their choice of location. The critical importance of social improvement was realised as early as the 1920s . H. Mess[11], referring at that time to the declining nothern cities, suggests that only by means of better housing, better town-planning and higher social conditions would it be possible "that in the future ... an industrial town may no longer be a place in which few will live who can avoid doing so". A decade later E. Wilkinson[12] referring to the case of Jarrow and other Special Areas writes that their starvation of all the social amenities "has a deadening effect on the hope of getting private industry to those areas". M.P. Fogarty[13] referring to the prospects of development for Lancashire in 1945 writes "From the point of view of transport, of labour, of marketing and of other factors in costs it appears that (Lancashire) is at little or no disadvantage by comparison with the Midlands or South. One genuine disadvantage is the generally drab appearance of many ... towns and the poor quality of housing and social amenities, particularly from the point of view of employers, managers and officials and imported key workers in new industries which might alternatively be located in one of the most attractive areas in the South". Finally, recent research has shown that social amenities and particularly housing conditions are among the major factors controlling residential location. Furthermore, around 50% of the people who would generally consider moving with their present employer, are not prepared to move to certain particular areas, mainly because they are not satisfied with the amenities there. This reluctance is one of the reasons given by employers for not starting up or moving establishments to redevelopment areas. Thus, in the case of Britain, changes in the relative importance of the two factors controlling the Basic Image of a city, appears to follow closely the changes in the relative importance placed nationally on the social aspects of growth. The national attitude has been measured as the proportion of GNP spent on social services and a table showing its changes over the period 1801-1971 has been given. The trend of the slope m, however, cannot be formally derived on the basis of the available data. For the purposes of the model an estimate will be used, the derivation of which is described below.

The slope $m = \tan\theta$ of the cusp axis decreases as the relative importance of the Social Indicator increases.

For $\theta = 90^\circ$ (i.e. $m = \infty$) the Social Indicator plays no part in the definition of the Basic Image for a given city which depends entirely on the value of the Industrial Indicator (Figure 5.3). As I have mentioned in Chapter 3 the projection of the cliff top (AB) represents the locus of breaking points for a city undergoing sudden loss of attractiveness. The projection of the cliff foot (AD) corresponds to the set of turning points for cities going through a sudden transition from decline to prosperity. T_1T_2 , T_3T_4 are typical trajectories for the Basic Image of a given city on the behaviour space and $T_1'T_2'$, $T_3'T_4'$ are their respective projections on the control space.

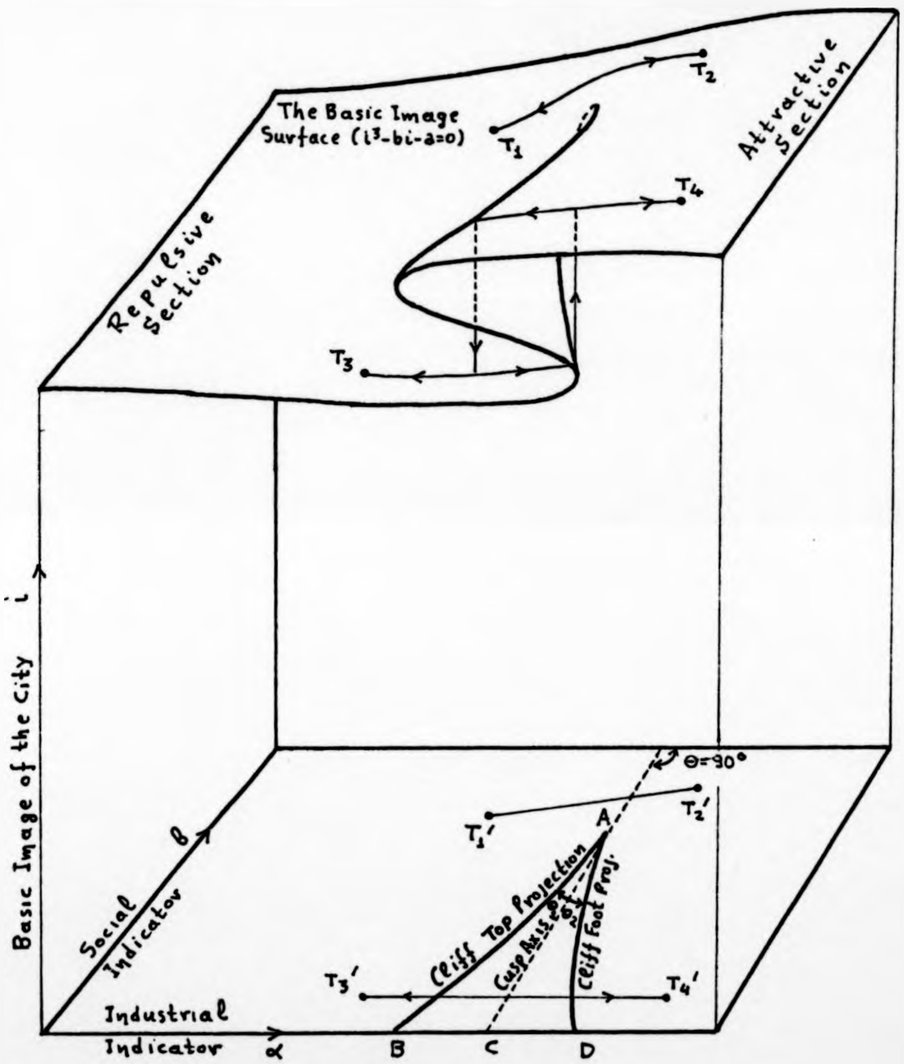

Figure 5.3

The Graph of Basic Image for θ = 90°

For $45° < \theta < 90°$ (i.e. $1 < m < \infty$) both indicators contribute towards the definition of the Basic Image. The influence of the Social Indicator, however, although it increases as $\theta \to 45°$ (i.e. $m \to 1$), never becomes decisive. For $\theta = 45°$ (i.e. $m = 1$) an industrial city can still remain attractive even if its Social Indicator reaches its minimum value (Figure 5.4).

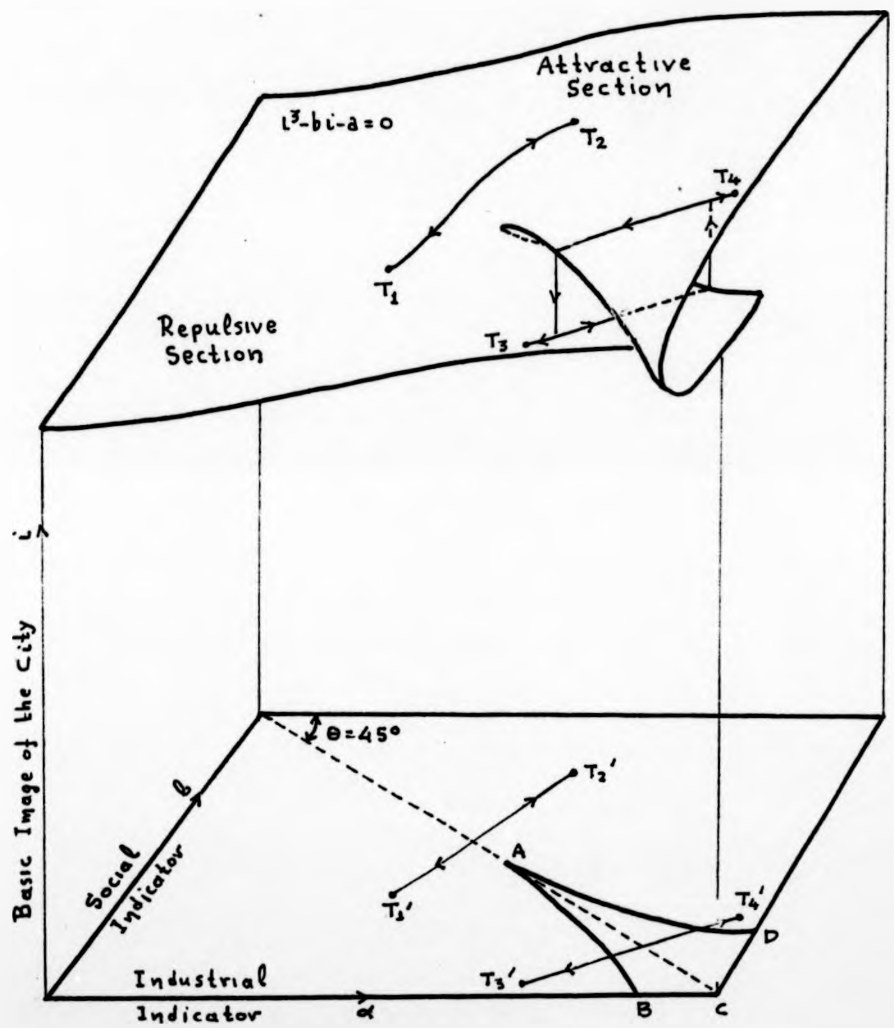

Figure 5.4

The Graph of Basic Image for $\theta = 45°$

For $\theta < 45°$ (i.e. $m < 1$) the influence of the Social Indicator becomes increasingly decisive. No industrial city can be attractive any more unless its Social Indicator exceeds an increasing minimum value. For $\theta \approx 30°$ (i.e. $m \approx 0.58$) even the highest Industrial Indicator can be offset by low social conditions (Figure 5.5).

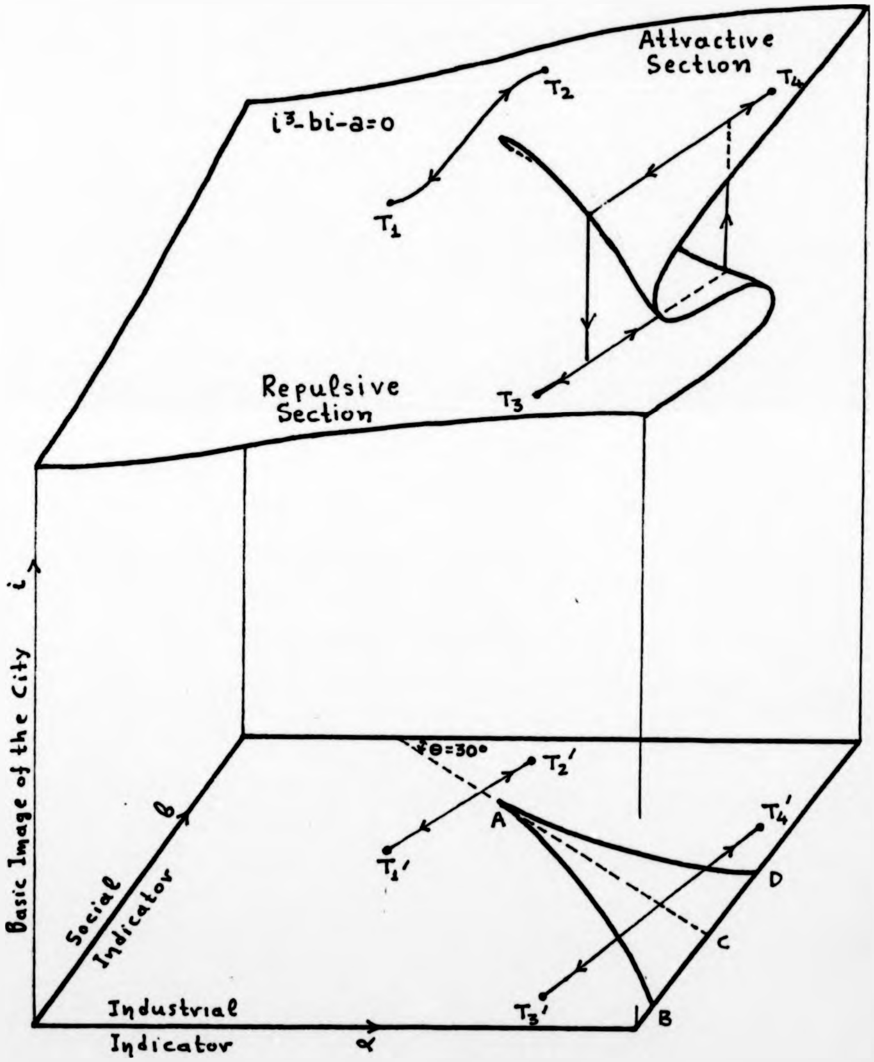

Figure 5.5

The Graph of Basic Image for $\theta = 30°$

Finally, as $\theta \to 0°$ (i.e. $m \to 0$) the Industrial Indicator becomes gradually less powerfull and for $\theta = 0°$ it has no effect on the Basic Image of a given city (Figure 5.6).

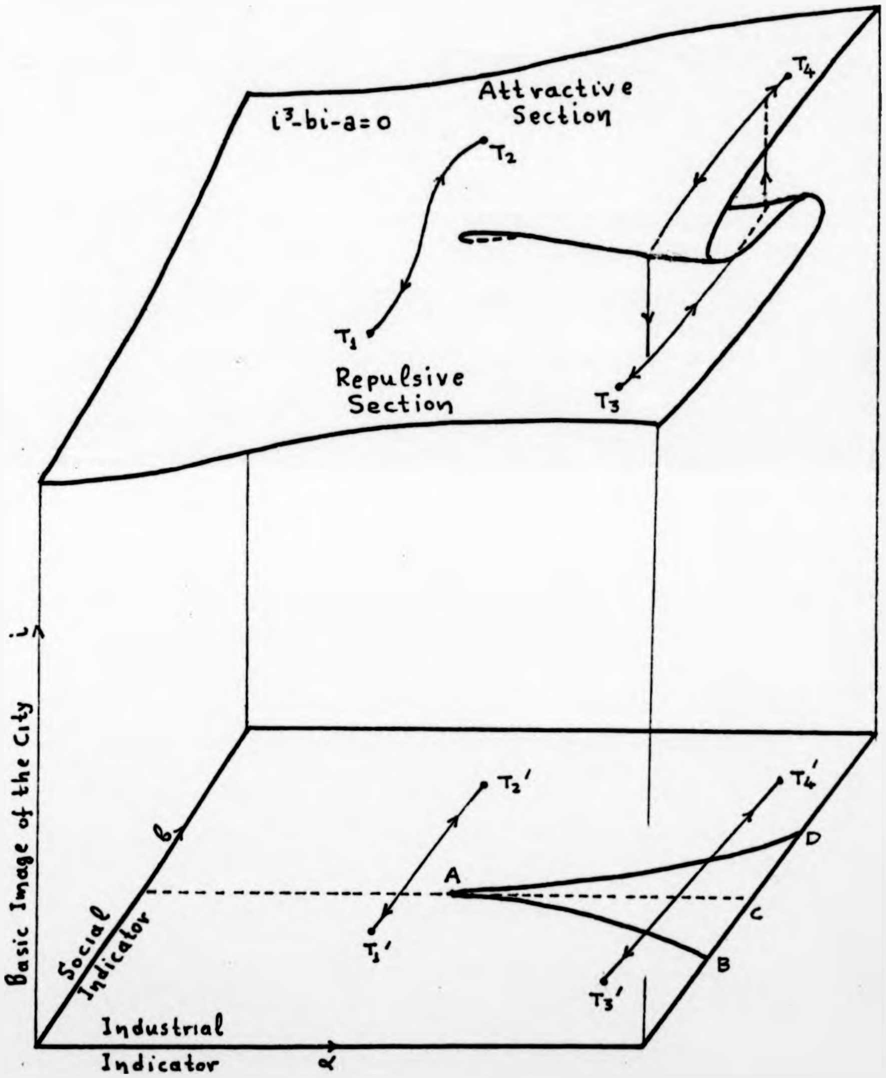

Figure 5.6

The Graph of the Basic Image for θ = 0°

The available empirical evidence leaves no doubt that for the period prior to 1900 the Social Indicator played an insignificant part in in the definition of the Basic Image for a given city. Therefore, it seems justifiable to assume that the value of m re-

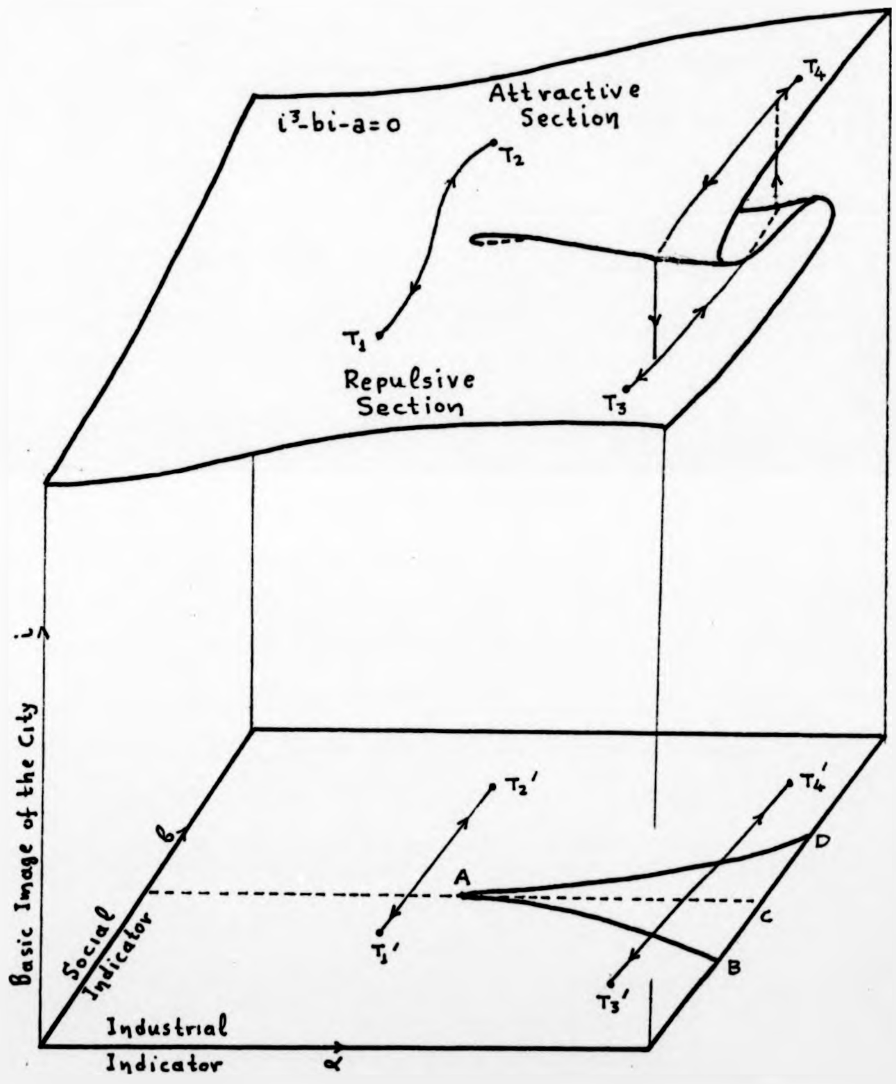

Figure 5.6

The Graph of the Basic Image for $\theta = 0°$

The available empirical evidence leaves no doubt that for the period prior to 1900 the Social Indicator played an insignificant part in in the definition of the Basic Image for a given city. Therefore, it seems justifiable to assume that the value of m remained greater than 1 for the whole of that period. The 1880s saw an increasing public concern for social conditions and in the words of M. Bruce[3] "they were indeed a turning point" in this aspect. On the other hand, the turning point in the role of the Social Indicator although not clearly definable, it seems — on the basis of the preceded discussion — to have taken place at a later date and possibly during the first decade of the 20th century. The introduction of minimum environmental standards revealed the increasing concern for the results of uncontrolled urban growth and, on the other hand, the appearance of a new generation of less resource-oriented industries and the improvement of transportation methods gave both people and industries a wider coice of location. The 1920s brought clear signs of the new role of the Social Indicator which became even more decisive in the post war period. On the basis of the analysis presented so far the following set of values have originally been chosen for the purposes of the model (Table 5.2). Test runs however, will also be performed with alternative sets ofvvalm values.

TABLE 5.2

CHANGES OF THE SLOPE,m , OVER TIME

Year	θ	m
1800	80°	5.6713
1825	75°	3.7320
1850	70°	2.7474
1875	60°	1.7320
1900	45°	1.0000
1925	35°	0.7002
1950	30°	0.5773
1975	25°	0.4663

Values of θ for the years not shown in the Table 5.2 are computed by interpolation and are shown in Figure 5.7.

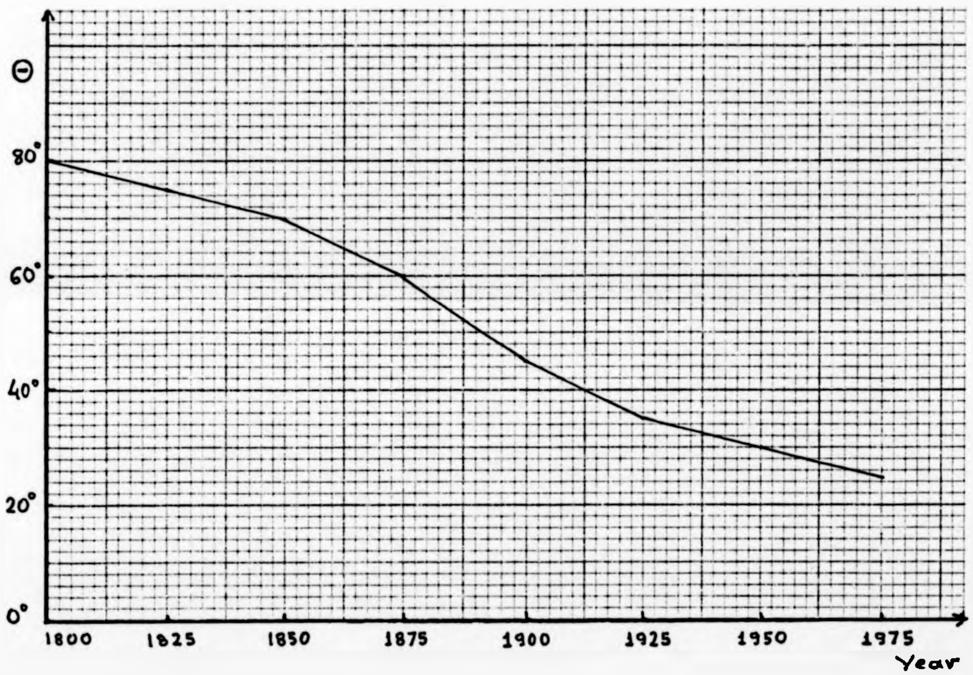

Figure 5.2

Changes of θ over Time

At this point, one may argue that the changing role of the Social Indicator should have been further emphasised by keeping θ considerably larger during the 19th century and allowing it to decrease suddenly after 1900. This is a plausible, although debatable argument. Sociologists and historians – as I have noted in Chapter 1 are divided between advocates of the theory of gradual social changes and those who support the thesis of sudden changes. For the purposes of this study a continuous trend has been chosen to represent the changing importance of the Social Indicator; justification for this choice is given below. From the construction of the model a city can jump from an attractive to a repulsive state, and vice-versa, as a result of:

(i) changes in the value of its indicators;

(ii) changes in the value of θ;

(iii) combination of (i) and (ii).

If the model —using a discontinuous representation for the relative weight of the Social Indicator - shows that the Basic Image of a given city undergoes a sudden change aroundthe turn of the century there may be a dispute on whether this expresses a real change in the city's attractiveness or it is due to a sudden change in the value of θ. The use of a smoother trend —like the one shown in Figure 5.7— ensures that any discontinuities in the trend of the city's Basic Image are generally due to changes in the values of its indicators; sudden jumps resulting from slow changes in the value of θ alone, although theoretically possible they are practically unlikely. Furthermore, if the model shows signs of discontinuity for a given city under a smooth rate of change for θ, the use of a less smooth trend will give results of quantitative differences only.

5.4 MODELLING THE DERIVATION OF m

Table 5.2 gives the trend of the slope, m, over the period covered by the model. The following two equations express it mathematically and in the form it will be used in the model; Figure 5.8 illustrates it graphically.

```
0000  M.K=TABHL(MT,TIME.K,0,175,25)
0001  MT*=5.6713/3.7320/2.7474/1.7320/1/0.7002/0.5773/0.4663
```

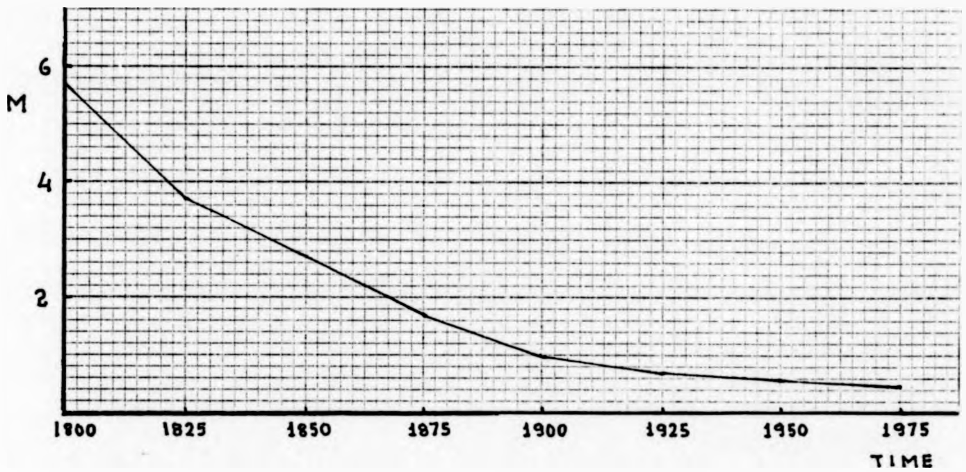

Figure 5.8

As I have mentioned in the Introduction the proposed model has been constructed to describe cities where the majority of economically active persons work and live within the politically fixed boundaries. However, it may also be used – with slight modifications only – to describe cities functioning within a wider commuter region. The Cusp Location Submodel, as constructed, can be applied to both cases without any change.

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Chapter 6

Basic-Image Derivation Submodel

Figure 6.1 relates the derivation of the Basic Image to the rest of the model.

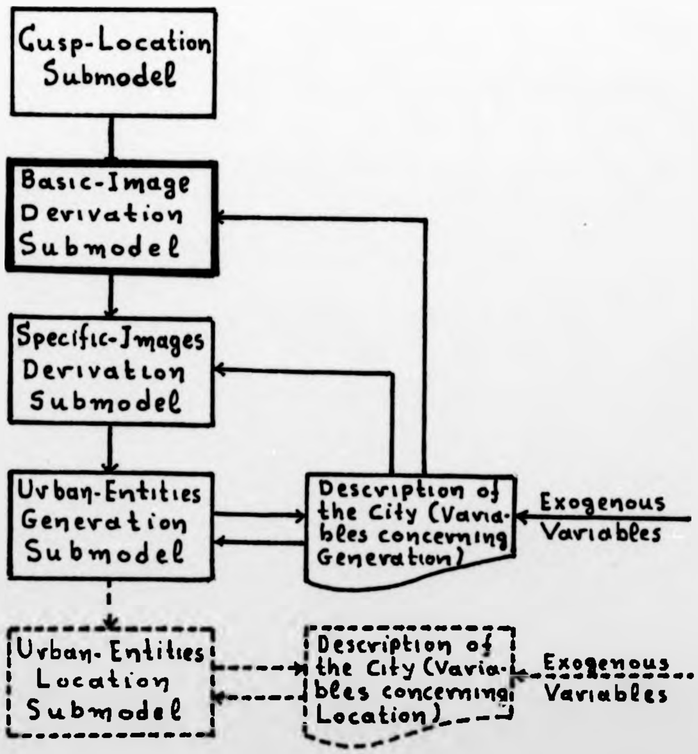

Figure 6.1. Basic Image derivation Submodel as part of the complete model

The concept of the city's Basic Image was introduced in Chapter 3 and the main conclusion of the analysis undertaken there was that the Basic Image of a city may be considered as a function of two measurable conflicting factors: the Industrial and the Social Indicator. I will now define those two indicators, suggest ways of measuring them and finally model the derivation from them of the value of the Basic Image.

6.1 FACTORS CONTROLLING THE BASIC IMAGE

People and industries move in to or out of a given city on the basis of their perception of its relative advantages and disadvantages. Their mobility is therefore a function of a multitude of factors the main ones, as identified by empirical evidence (Cullingworth[1], Harris and Clausen[2], Hunter and Reid[3], Luttrell[4], Report on the Location of Industry[5], Rhodes and Khan[6], Sant[7], Townroe[8]) are listed below. I shall call this the "complete list".

Access to materials and markets
Availability of land
Regional influence
Environmental quality
Availability of suitable housing
Labour quality
Labour availability
Job availability
Job prospects
Financial assistance.

In a country like Britain mobility is largely a voluntary process; although Government intervention aims to achieve a more balanced economic and social developmentthe control mechanisms available are mostly negative and therefore able to influence mobility but not direct it. Consequently, the vital part of any attempt to impose or sustain the attractiveness of a given city must be "the provision and maintenance of a framework in which voluntary mobility can flourish and this must inevitably be a task for general policy rather than direct measures on the mobility processes themselves" (Hunter and Reid[3]). Basic Image has been defined as the measure of the real state of a city; hence it must be a function of such factors which, if properly developed will form the foundations for informed voluntary movement. In certain cases the cause and effect relationships between factors of the above list and the process of mobility are not very clear. Basic Image must obviously be seen as a function of predominantly causal factors; hence only those which are not normally considered a direct result of the mobility process itself may be included. The first five factors of the above list clearly satisfy this requirement; in the case of the remaining five factors, however, the decision is not obvious. The presence of skilled and professional employees, for example, although a very important factor in itself, may be considered as a natural property of a city with an attractive Basic Image. On the other hand any attempt to direct qualified employees into an unattractive area, as a way of improving its image, will be expensive and ineffective, unless it is part of a general program aiming to create an environment where the informed voluntary movement of manpower can be sustained. Similarly, the availability of promising and well-paid jobs may be justifiably considered as a normal feature of an attractive city; on the other hand, the exogenous provision of jobs per se, cannot solve the problems of a declining area. Finally, financial assistance, one of the measures employed to lanced economic and social developmentthe control mechanisms available are mostly negative and therefore able to influence mobility but not direct it. Consequently, the vital part of any attempt to impose or sustain the attractiveness of a given city must be "the provision and maintenance of a framework in which voluntary mobility can flourish and this must inevitably be a task for general policy rather than direct measures on the mobility processes themselves" (Hunter and Reid[3]). Basic Image has been defined as the measure of the real state of a city; hence it must be a function of such factors which, if properly developed will form the foundations for informed voluntary movement. In certain cases the cause and effect relationships between factors of the above list and the process of mobility are not very clear. Basic Image must obviously be seen as a function of predominantly causal factors; hence only those which are not normally considered a direct result of the mobility process itself may be included. The first five factors of the above list clearly satisfy this requirement; in the case of the remaining five factors, however, the decision is not obvious. The presence of skilled and professional employees, for example, although a very important factor in itself, may be considered as a natural property of a city with an attractive Basic Image. On the other hand any attempt to direct qualified employees into an unattractive area, as a way of improving its image, will be expensive and ineffective, unless it is part of a general program aiming to create an environment where the informed voluntary movement of manpower can be sustained. Similarly, the availability of promising and well-paid jobs may be justifiably considered as a normal feature of an attractive city; on the other hand, the exogenous provision of jobs per se, cannot solve the problems of a declining area. Finally, financial assistance, one of the measures employed to relieve economic pressure and generate activity in depressed areas is obviously also more effective when used within a favourable framework. On the basis of those arguments it was finally decided that the last five factors of the "complete list" do not meet the set requirements and should be therefore excluded from the Basic Image. Their exclusion however, is by no means an indication of lesser importance; indeed they are as significant as any of the other factors, at least for some of the groups of potential movers. The only difference is that they are implicitly related to the process of mobility itself and consequently their full impact on the process of a city's development is felt only when they are operating within a favourable environment.

Concluding I list the factors which are considered as controlling the Basic Image of a city. I shall be referring to this as the "basic list".

Access to materials and markets
Availability of land
Regional inluence
Environmental quality
Availability of suitable housing.

Factors included in the complete list", presented at the beginning of this section, but excluded from the "basic list" will be used in Chapter 7 for the generation of Specific Images.

6.1.1 <u>Factors Controlling the Industrial Indicator</u>

Industrial Indicator expresses the industrial potential and economic profitability of a given city. Among the five factors of the "basic list" access to materials and markets and availability of land for industrial expansion are obviously the factors controlling it exclusively. Regional influence may also be considered as partly affecting it. My objective in this section is to take a closer look at those factors.

Access to materials and markets: The model treats access to materials and markets as a single but composite factor. The relative importance of its two components has been changing over time and the successful representation of this factor requires a clear understanding of their respective roles. Let me start with the influence of materials. All manufacturing industry performs some operation, or a series of operations, upon a supply of materials and consequently all industrial units are concerned with their location relative to them. The importance of a favourable location during the 19th century urbanisation is undeniable and its major contribution to the sudden rise of many cities in the northern part of England during that period is widely recognised. With the changing face of industry and the great improvements in transportation methods, proximity to natural resources has naturally lost some of its significance. However, the sudden invigoration of various Scottish cities as a direct result of the recent oil discoveries in the North Sea show that it is still an important factor. In the words of R.C. Estall and R.O. Buchanan[9] "despite the declining influence of raw materials on location decisions it remains true that all enterpreneurs will be concerned to examine their situation with regard to their essential material-supplies".

Access to markets has always been an important factor for industries catering for consumers' needs and in which direct contact is necessary. During the 19th century the growth of retail marketing —the main consumer-oriented industry of that period— was "determined in its location pattern by the distribution of population concentrations" (Lee[10]). The first large retail outlets and the origins of almost all chain stores lay in the major cities. By contrast, market attraction was of very little significance for the manufacturing industry which was the basis of industrial activity at that time. Therefore the overall influence of markets on industrial distribution was considerably less than that of raw materials. The 20th century, however, brought major changes. The changing face of manufacturing industry and the growth of the consumer-orientated sector of it reinforced the attraction power of the market. Writing in 1939 about industrial location S.R. Dennison[11] states that "...it is worth noting that a large part of the industrial world appears to believe that (market) is the dominant factor". At the same time a report published by the Federation of British Industries put in the place of "nearness to materials" the "necessity for location near to the principal market" as the primary industrial location factor. Today the importance of proximity to a large market is generally recognised; in the words of D. Eversley[12] "no serious plans should be made for any area which will not have for its centre a present or future city of at least 250,000 and the aggregate of the population of that centre and its services hinterland should not normally be less than 750,000.

Access to markets and resources is not an easily quantifiable factor. Discovery of new deposits of raw materials and the establishment of new markets, but mainly the change in the concept of distance as the result of improvements in transport technology, makes the measurement of proximity rather difficult. For the purposes of the model an Accessibility Index is introduced as a function of the relative position of the city with regard to both markets and resources. The Accessibility Index is given exogenously and details about its derivation are presented in Appendix 2. The average of the indices constructed for the largest industrial cities represents the Accessibility Index of a hypothetical city I shall be referring to it as "normal" city and it will be taken to represent the average of all the cities in the country to which the model is applied. For the purposes of the model the "normal city" is considered as the average of eighteen cities spread uniformly throughout England and Wales (Figure 6.2).

Figure 6.2 The eighteen selected cities

Accessibility Index of value higher than the normal indicates a favourable position while an Index of lower value indicates a city far from raw materials and large markets.

Availability of land: Availability of land for industrial expansion has always been one of the main factors influencing the development of a city. A typical example of its power in early stages of urbanisation is the case of Coventry. At the end of the 18th century the city of Coventry was almost surrounded by the so-called Lammas and Michaelmas Lands where building was not allowed without an Act of Parliament which was not easily obtainable. For half the year they belonged exclusively to their proprietors but for the other half the freemen had a right of pasture over them. This custom, sensible enough for the 14th century when the citizens could not easily feed their animals during the winter, is widely recognised as the main reason for causing Coventry to miss the early stages of Industrial Revolution and have a slow development until the end of the 19th century when the land use restrictions were lifted (Prest[13]). Land is equally important today. Recent research has shown that availability of land for expansion is the major purely industrial factor in determining the attractiveness of a certain area. Furthermore Sant[7] after a detailed analysis of the various factors which attract industries concludes that his results "confirm most strongly the findings of those who have suggested that lack of space is the major factor pushing firms out of the urban regions". Sant's conclusion also underlines a very important property of land availability: its rather "negative" influence on the Image of a city. Indeed while an over abundance of land is not a particularly attractive feature, it is shortage of land that constitutes a repulsive feature of critical imporatnce.

Measuring land availability is a delicate subject. If the city area is considered fixed as in the case of a city surrounded by a clearly defined green belt, then land availability may be measured as the fraction of the city area which is available for expansion. Generally, however, a city is allowed to expand in order to accommodate any further growth. Although expansion is not limitless the measure presented above is meaningless in this case. The measure chosen for the purposes of the model is the density of population in the region surrounding the city under study. High density indicates a high degree of urbanisation and makes further potential expansion more difficult but not impossible. Local restrictions on land use are also taken into account separately whenever it is necessary. Details on measuring land availability are given in Appendix 2.

Regional influence: Potential movers into a given city are not only influenced by the conditions of the city itself but also by the general outlook of the surrounding area or in other words by the corresponding regional image. Indeed recent research (Harris and Clausen[2]) has shown that a large proportion of prospective movers are reluctant to move into particular regions for no specific reason but a general "lack of appeal" for them. Therefore the model assumes that the Industrial Indicator of a given city is a function not only of access to materials and markets and availability of land but also of a third factor which expresses the image of its surrounding region. In a general case where the proposed model may be used as part of a national model such a factor may be derived endogenously in a way similar to that followed for the Basic Image of the city itself. In the present case, however, a simple factor must be chosen and its measure has to be given exogenously. Several factors may be considered as expressing the image of a region the most common being the average regional income and the average regional rate of unemployment. For the purposes of the model the latter factor has been selected on the ground of data availability. High rate of regional unemployment is generally considered as a favourable influence on the city's Industrial Indicator,because it implicitly suggests the existence of a large pool of potential employees.

6.1.2 Factors Controlling the Social Indicator

Social Indicator expresses the quality of life in a given city. The main factors controlling it are environment and housing. As in the case of the Industrial Indicator regional influence may also be considered as partly affecting it. My objective in this section is to discuss each of those factors.

Environmental quality: A healthy environment is probably the basis for a high quality of life in a given city. Although environment is a unity wherein many elements interact, several reparate problems may be distinguished: air-pollution, water-pollution, noise, solid waste disposal and the dereliction of land. Such problems, in an age of rising aspirations and growing demand for a better environment, contribute to the depopulation of areas debased by industrial mess. Recent research has established a correlation between outward migration from districts of severe dereliction and inward migration to areas of low spoliation, especially among young and qualified workers. An unpleasant environment is also a deterrent to modern industry. Industrialists are becoming increasingly critical of the areas in which they choose to establish their new business and potential industrial investment has been lost for many cities because the environment was degraded (Barr[14]).

For the purposes of the model two aspects of environmental quality are considered; land dereliction and atmospheric pollution.

Industrial ruins are generally the major contributors to land dereliction. In the present case the fraction of Unfit Industrial Buildings among the total industrial stock of the given city is taken as a measure of dereliction. Excessive and uncontrolled industrial activity is the principal generator of atmospheric pollution. For the purposes of the model the ratio of the number of industrial units per head – expressing a measure of industrial activity – over the number of Fit Housing Units per head – expressing a measure of residential activity – is taken as a measure of pollution. A value of this ratio greater or less than the normal level respectively.

Availablity of suitable housing: A recent OECD[15] seminar claimed that in Britain "the principal obstacle to geographical mobility is generally agreed to be the shortage of suitable housing". Although the relationship between housing and mobility is not very well documented the available evidence seems to support this view. In the present case two aspects of the housing conditions in a given city are considered; housing availability and housing quality. The first is expressed simply as the ratio of the number of families over the number of available houses. For the quantification of the second a Housing Quality Index has been introduced as follows. A housing quality scale has been defined and the scores for the various types of housing units are fixed. Obviously High-Cost Housing Units score the highest marks (3) in this scale while Unfit Housing Units score the lowest (0). Medium and Low-Cost Houses score 2 and 1 points respectively. The average score for the housing stock of a given city represents its Housing Quality Index.

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<u>Regional influence</u>: The model assumes that the Social Indicator of a given city is a function not only of environmental quality and housing availability but also a function of the corresponding regional image, expressed by the average regional unemployment rate. Contrary to the case of the Industrial Indicator, high rate of regional unemployment is generally considered as an adverse influence on the city's Social Indicator because it implicitly suggests lower incomes and lower standard of living.

Concluding, I could say that all three factors controlling the Social Indicator are less powerful as factors of location than they are as factors of dislocation. In other words, they act in a rather negative way in the sense that they are generally more influential in stopping people from moving into repulsive areas rather than pushing them into a particular attractive area.

6.3 <u>SOLUTION OF THE IMAGE EQUATION</u>

Having dealt with the problems of definition and measurement of the two indicators controlling the Basic Image of a city I shall now move on to the solution of the Image Equation. I have already suggested in Chapter 3 that the graph of the Basic Image is qualitatively equivalent to the cusp catastrophe graph (for proof see Chapter 11); consequently the value i of the Basic Image is given as a solution of the equation:

$$i^3 - bi - a = 0 \qquad (6.1)$$

where

$$\left.\begin{aligned} a &= m(\alpha - \alpha_0) + (\beta - \beta_0) \\ b &= (\alpha - \alpha_0) - m(\beta - \beta_0) \end{aligned}\right\} \quad \text{if } m \leqslant 1 \text{ (i.e. } \theta \leqslant 45^\circ)$$

and

$$\left.\begin{aligned} a &= (\alpha - \alpha_0) + (1/m)(\beta - \beta_0) \\ b &= (1/m)(\alpha - \alpha_0) - (\beta - \beta_0) \end{aligned}\right\} \text{ if } m > 1 \quad (\text{i.e. } \theta > 45^\circ)$$

α, β measures of the Industrial and Social Indicators respectively;

(α_0, β_0) the vertex of the cusp on the control space;

m the slope of the cusp axis as supplied by the cusp location submodel (Chapter 5).

Equation (6.1) is a third order algebraic equation having three distinct roots in general. My primary concern, therefore is to develop a method for choosing the right root i.e. the root corresponding to the real value of the city's Basic Image. The type of roots of an algebraic equation depends primarily on its determinant. In the case of equation (6.1) the determinant is given by

$$\Delta = \frac{a^2}{4} - \frac{b^3}{27}$$

Depending on the sign of Δ the three following cases may be distinguished:

(i) If $\Delta < 0$ then equation (6.1) has one real and two complex conjugate roots.

(ii) If $\Delta > 0$ then equation (6.1) has three distinct real roots.

(iii) If $\Delta = 0$ then equation (6.1) has three real roots two of which are equal.

Case (i) presents no problems. The only real root will be the value of the Basic Image.

Case (ii) is more complicated since it offers a choice between three roots. In the case of the cusp catastrophe graph, however, one of those roots represents an unstable state and it cannot be considered as a potential value of the Basic Image. A closer study of the properties of those three roots reveals that they are never all of the same sign and also that the root representing the unstable state is always the absolutely smaller of the two roots with the same sign.

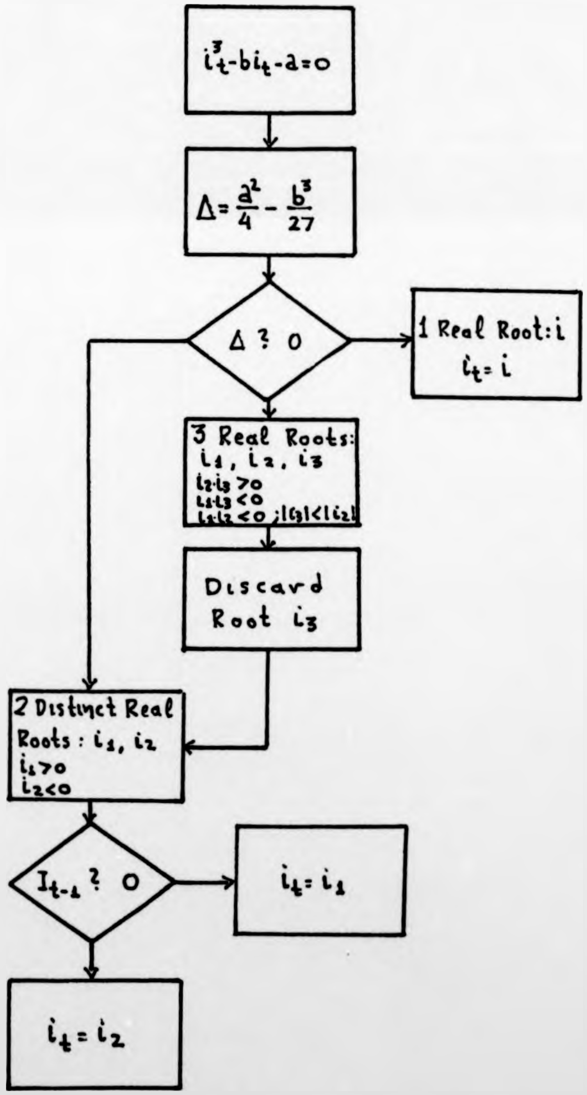

__Figure 6.3__

Solution of the Image Equation

Having discarded one of the roots, the choice between the remaining two is decided in the following way. Let me suppose that $i = i_{t-1}$ is the last value of the Basic Image before the determinant Δ becomes positive. If $i_{t-1} > 0$ then I must keep choosing the positive root as long as $\Delta > 0$. On the contrary if $i_{t-1} < 0$ then I must keep choosing the negative root.

Finally, case (iii) may be considered as special case of case (ii). The two distinct roots are always of opposite sign and the method of choice suggested for case (ii) may be equally well applied in this case also.

The general process of root choice is illustrated in Figure 6.3 .

6.4 MODELLING THE DERIVATION OF BASIC IMAGE

Having presented the factors which control the Basic Image of a city I shall now move on to describe how they combine to give us its value. Figure 6.4 illustrates graphically the procedure followed for modelling the derivation of the Basic Image.

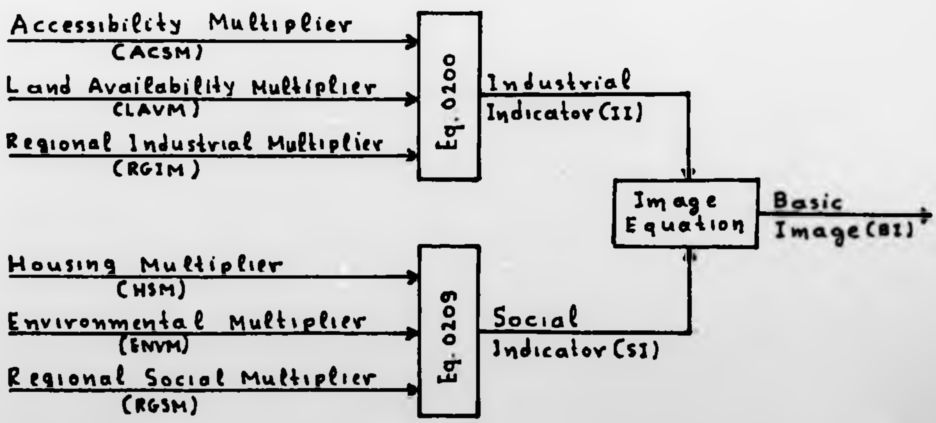

Figure 6.4 Derivation of the Basic Image

The following set of equations simulate the process shown in Figure 6.4. An alphabetical list of all the terms appearing in this section is given in Appendix 3.

```
0200   II.K=EXP((1/3)(LOGN((ACSM.K)(LAVM.K)(RGIM.K))))

0201   ACSM.K=TABHL(ACSMT,RACSIX.K,0,2.5,0.25)
0202   ACSMT*=0.10/0.10/0.45/0.80/1.00/1.20/2.00/2.90/3.70/3.85/4.00

0203   LAVM.K=SWITCH(LAVM1.K,LAVM2.K,LURF.K-1)
0204   LAVM1.K=TABHL(LAVM1T,RUPDR.K,0.25,2.5,0.25)
0205   LAVM1T*=1.00/1.00/1.00/1.00/0.90/0.80/0.60/0.50/0.45/0.40
0206   LAVM2.K=LURF.K

0207   RGIM.K=TABHL(RGIMT,RRGUN.K,0,2.50,0.25)
0208   RGIMT*=0.50/0.60/0.70/0.85/1.00/1.20/1.30/1.40/1.30/0.85/0.40

0209   SI.K=EXP((1/3)(LOGN((HSM.K)(ENVM.K)(RGSM.K))))
0210   HSM.K=MIN(FHAVM.K,HQLM.K)

0211   FHAVM.K=TABHL(FHAVMT,1/RFHR.K,0.8,1.2,0.05)
0212   FHAVMT*=0.25/0.30/0.50/0.60/1.00/1.15/1.40/2.10/2.40

0213   HQLM.K=TABHL(HQLMT,RHQLIX.K,0.5,1.5,0.1)
0214   HQLMT*=0.25/0.30/0.40/0.50/0.70/1.00/1.15/1.30/1.70/2.10/2.40

0215   ENVM.K=MIN(TSQM.K,ARQM.K)

0216   TSQM.K=TABHL(TSQMT,1/(RUFIBF.K+0.000001),0,2.5,0.25)
0217   TSQMT*=0.25/0.40/0.50/0.70/1.00/1.10/1.15/1.30/1.70/2.10/2.40

0218   ARQM.K=TABHL(ARQMT,RRIAR.K,0.6,1.6,0.1)
0219   ARQMT*=0.25/0.40/0.50/0.70/1.00/1.10/1.15/1.30/1.70/2.10/2.40

0220   RGSM.K=TABHL(RGSMT,RRGUN.K,0,2.00,0.25)
0221   RGSMT*=1.40/1.37/1.35/1.15/1.00/0.80/0.60/0.40/0.30

0222   ALFA.K=II.K/2
0223   BETA.K=SI.K/2

0224   BIM.K=TABHL(BIMT,BI.K,-1,1,0.10)
0225   BIMT*=0.125/0.125/0.125/0.150/0.200/0.250/0.350/0.450/0.750/0.850/
X      1/1.150/1.300/1.900/2.250/2.500/2.800/3.100/3.550/3.850/4
```

Equation 0200 expresses the value of the Industrial Indicator as a product of three multipliers representing the three factors which have been considered as affecting it. For the purposes of the model, when a quantity Q is expressed as a product of a number of multipliers the following formula for the standardisation of its range is used.

$$Q = \sqrt[n]{(M_1)\ (M_2)\ \ldots\ (M_n)}$$

where,

$$M_1 = f(\mu_1),\ M_2 = f(\mu_2),\ldots,M_n = f(\mu_n)$$

are multipliers obtained as non-linear functions of measured variables $\mu_1, \mu_2, \ldots, \mu_n$. If all the multipliers are of the same range, normally $[0,2]$, then the range of their product is $[0,2^n]$ and consequently the range of Q is also $[0,2]$. In certain cases however, the dominance of a particular multiplier needs to be emphasised. This may be done by increasing its range. In such a case, the range of the remaining multipliers must be modified so as the range of their product to remain the same i.e. $[0,2^n]$. In this particular case

$$II = \sqrt[3]{(ACSM)(LAVM)(RGIM)}$$

where,

II = Industrial Indicator

ACSM = Accessibility Multiplier

LAVM = Land Availability Multiplier

RGIM = Regional Industrial Multiplier

Accessibility Multiplier – expressing the influence of the city's geographical position – is the dominant one and its range is taken as $[0,4]$. By restricting the range of the remaining two multipliers to $[0,1.59]$ I maintain a range of $[0,2^3 = 8]$ for their product and con sequently a range of $[0,2]$ for the Industrial Indicator. Multiplication with unequal weights has been chosen as the more appropriate way of combining the three terms because it underlines the central importance of location without underestimating the significance of the remaining factors especially in certain specific cases.

Equations 0201-0208 define the multipliers used in equation 0200. The quantification of directly immeasurable quantities and relationships is always problematic and open to discussion. For the purposes of the model, the quantification of such relationships has been based on available data but also on assumptions consistent with generally accepted views expressed in urban literature. However, the prospective user of the model may easily modify any of the relationships if his underlying set of assumptions is different. The same holds for all the quantified relationships which will be presented in Chapters 6,7 and 8.

Equations 0201, 0202 describe the effect of a city's location – expressed by its Accessibility Index – on its Industrial Indicator. For the purposes of the model a simple relationship emphasising the "positive" influence of this factor has been used (Figure 6.5)

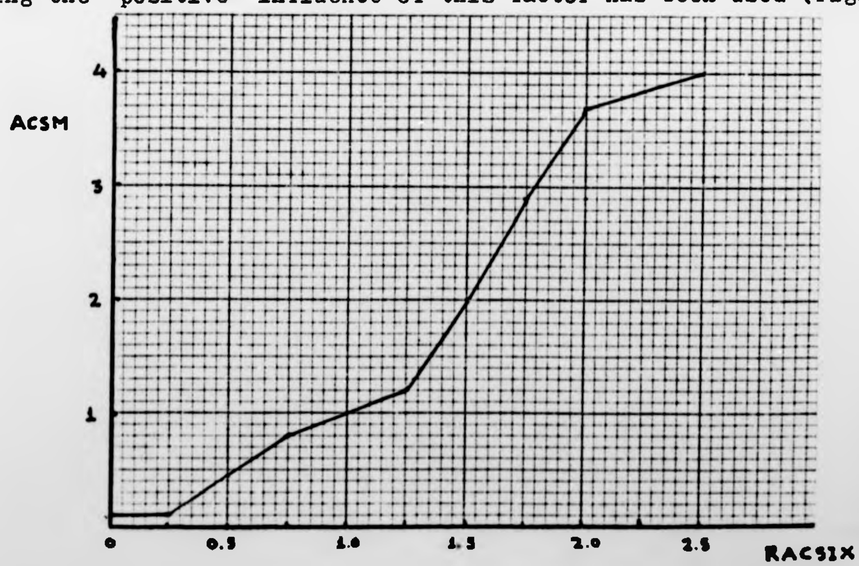

Figure 6.5

As long as the Relative Accessibility Index is close to that of the normal city its influence is rather limited. In case of larger discrepancies, however, its importance increases proportionately. The values of the Relative Accessibility Index corresponding respectively to the minimum and maximum values of the Accessibility Multiplier have been estimated on the basis of evidence presented in Appendix 2.

For the purposes of the model,Land Availability Multiplier (eq. 0203) is expressed as a function of two factors: population density within the region surrounding the city under study and local regulations for land use. Equation 0203 is constructed in such a way that LAVM1, LAVM2, representing the two factors mentioned above, are activated under different circumstances. When no local regulations for land use exist,only the first term is active. Hence, Land Availability Multiplier decreases as the population density increases (Figure 6.6). It reaches its minimum value when the population density becomes more than 2.0 times the maximum "tolerable level" defined in Appendix 2. For the purposes of the model,I assume that density lower than the "tolerable" value has no positive effect on the growth of the

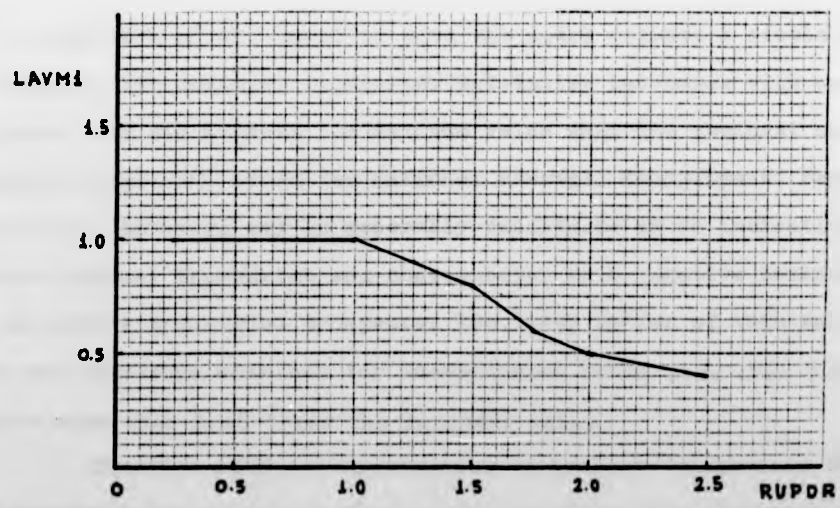

Figure 6.6

city. In the case of land use regulations the second term is activated and the Land Multiplier is expressed as a function of the Land Regulation Factor. Details for this factor are given in Appendix 2.

Finally equations 0207, 0208 and Figure 6.7 illustrate the effect of regional conditions on the city itself.

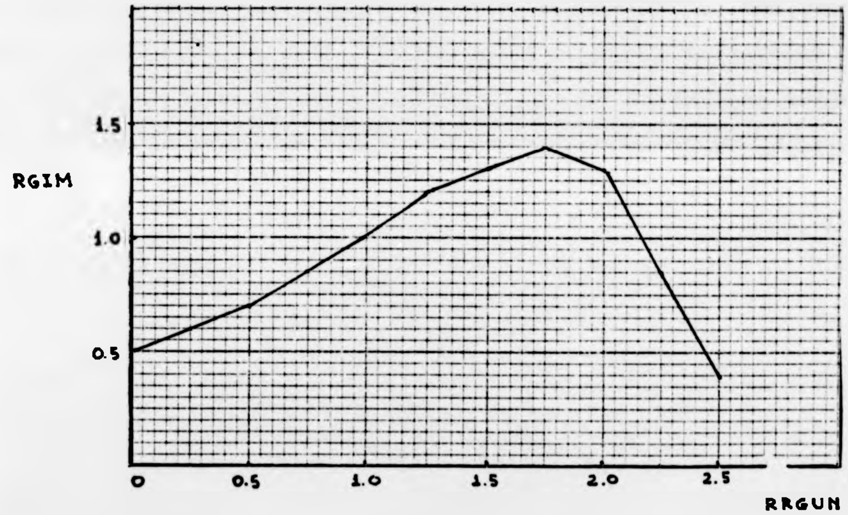

Figure 6.7

Due to the lack of any specific data the model assumes a simple relationship. The Regional Industrial Multiplier increases with unemployment rate and attains its maximum value when the regional unemployment is ap. 1.75 times the national average. Unemployment beyond this level, however, may be generally considered as an indication of severe regional depression and consequently as a negative influence on the city's industrial prospects. The lower values of this multiplier are therefore attained for unemployment rates less than 0.5 times or more than 2.25 times the national rate.

Equation 0209 is structurally equivalent to equation 0200 and generates the Social Indicator for the given city. Housing, environment and regional conditions are the factors which have been considered as controlling it. Equations 0210-0219 define the multipliers used in the previous equation.

For the purposes of the model, housing conditions are assessed in terms of both housing availability and quality. Therefore, the Housing Multiplier is expressed as a function of two relevant multipliers: Housing Availability and Housing Quality Multiplier (eq. 0210). The first multiplier is a function of the Fit Housing Ratio. Equations 0211, 0212 and Figure 6.8 illustrate their relationship.

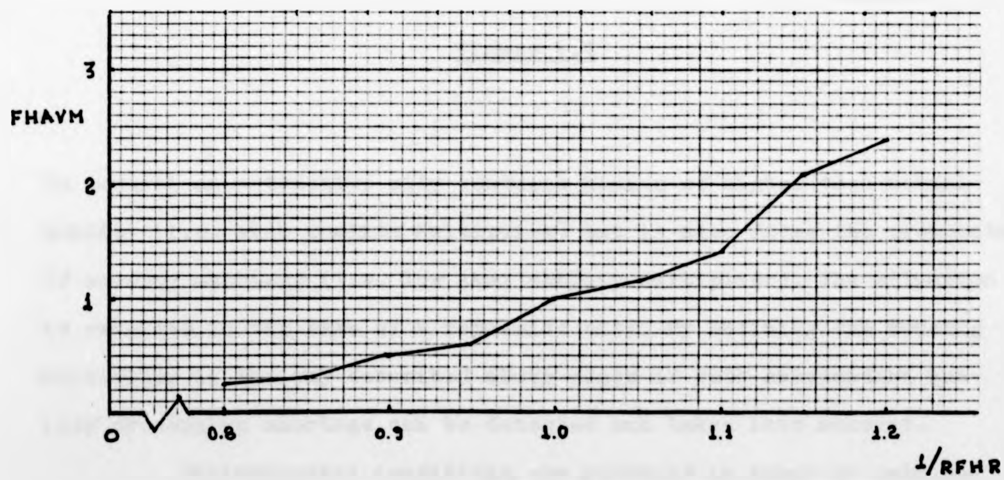

Figure 6.8

The second multiplier is a function of the Housing Quality Index. The form of the relationship is described in equations 0213, 0214 and Figure 6.9. It attains its maximum value when the Housing Quality Index becomes more than 1.5 times that of the normal city; in other words when the share of Unfit Housing Units in the city's housing stock is 3-4 times lower than the normal share. Its minimum value, on the other hand, corresponds to the case of a city with a share of Unfit Housing Units exceeding the normal one by a factor of 2-3

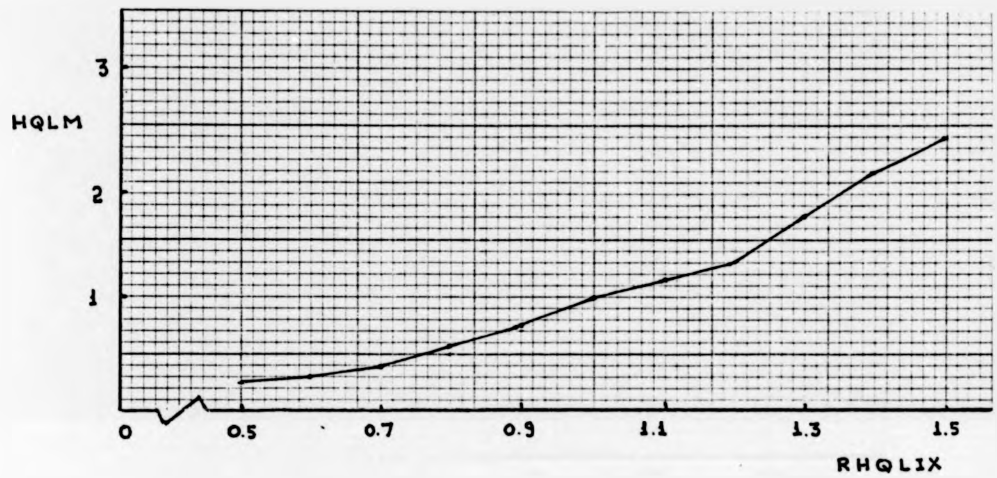

Figure 6.9

In general an attractive city contains houses of higher than normal quality (i.e. high Quality Multiplier) but it also faces the prospects of housing shortage (i.e. low Availability Multiplier). The situation is reversed in the case of a repulsive city. By defining the Housing Multiplier in the way described above cases of both substandard quality or housing shortage can be detected and taken into account.

Environmental conditions are assessed in terms of both dereliction and atmospheric pollution. Therfore the Environmental Multiplier is expressed as a function of two relevant multipliers (eq. 0215). Industrial ruins are the major contributors to the dereliction of an area. Hence. for the purposes of the model, Townscape Quality Multiplier is taken as a function of the proportion of Unfit Industrial Buildings among the total city stock. A simple relationship has been chosen which is described in equations 0216, 0217 and Figure 6.10.

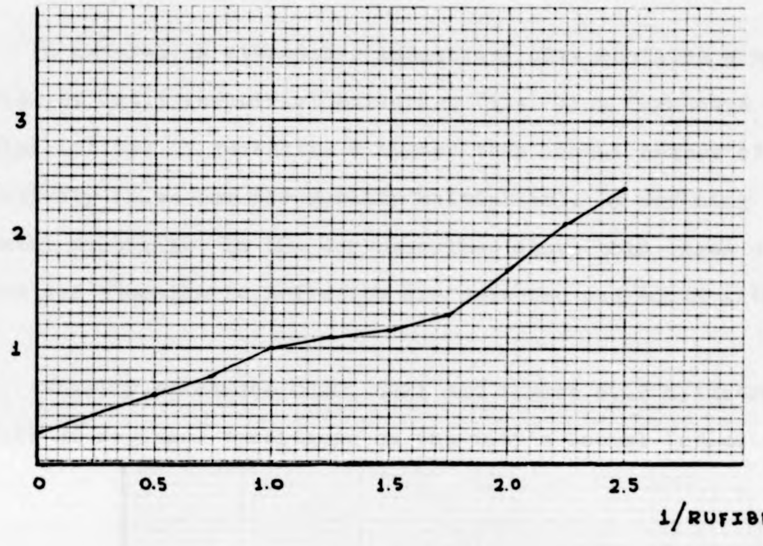

Figure 6.10

Excessive industrial activity and industrial waste is generally considered as the major factor of atmospheric pollution. For the purposes of the model the Air Quality Multiplier is expressed as a function of the Residential Activity/Industrial Activity Ratio. Their relationship is described by equations 0218, 0219 and Figure 6.11.

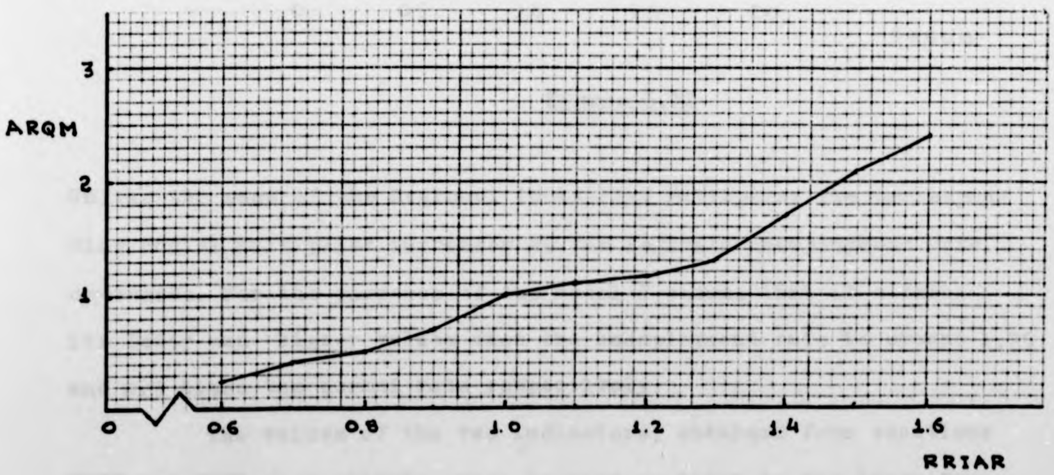

Figure 6.11

In general,an attractive industrial city contains a small proportion of Unfit Industrial Buildings (i.e. high Townscape Quality Multiplier) but it generates a higher than normal degree of industrial activity (i.e. low Air Quality Multiplier). By defining the Environmental Multiplier in the way described above both cases of dereliction and atmospheric pollution are detected and taken into account.

Finally,equations 0220, 0221 and Figure 6.12 illustrate the effect of regional conditions on the city's Social Indicator.

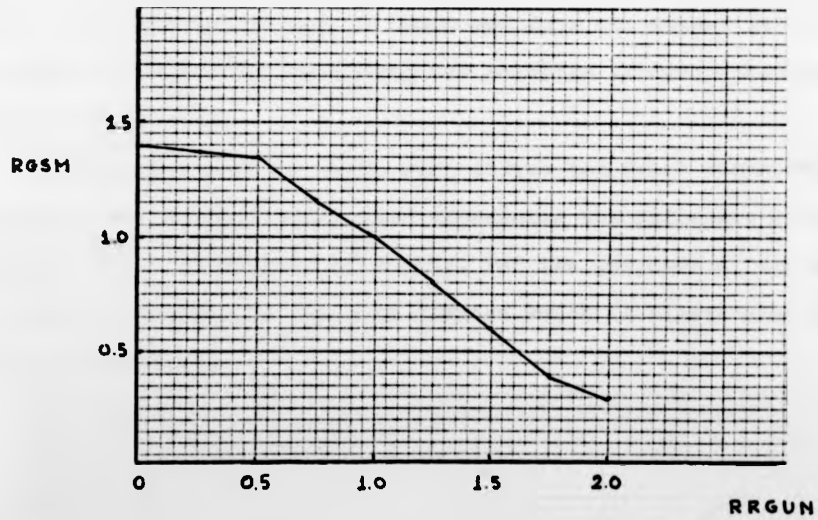

Figure 6.12

Unlike the case of the Regional Industrial Multiplier the corresponding Social Multiplier increases as the region's unemployment rate decreases. For the purposes of the model I assume that it attains its lower and higher values when the unemployment rate is around 1.75 and 0.5 times the normal rate respectively.

The values of the two indicators, obtained from equations 0200 and 0209 respectively, must be used as input to the Image Equa-

In general,an attractive industrial city contains a small proportion of Unfit Industrial Buildings (i.e. high Townscape Quality Multiplier) but it generates a higher than normal degree of industrial activity (i.e. low Air Quality Multiplier). By defining the Environmental Multiplier in the way described above both cases of dereliction and atmospheric pollution are detected and taken into account.

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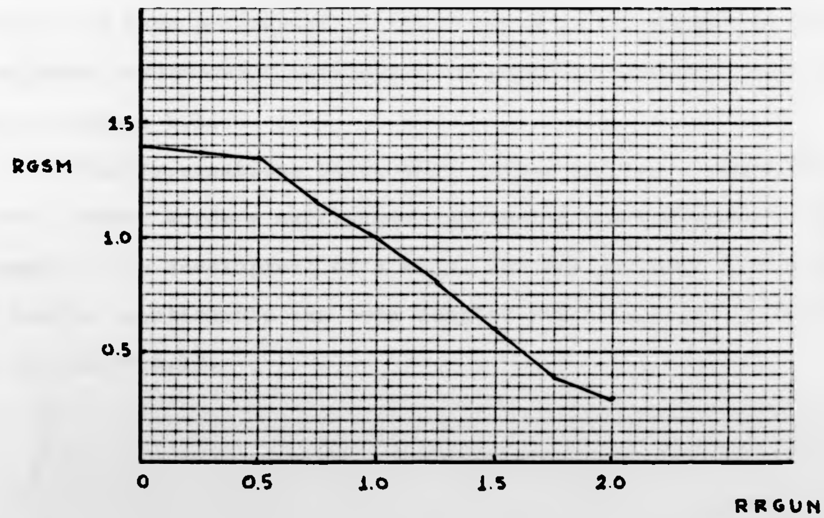

Figure 6.12

Unlike the case of the Regional Industrial Multiplier the corresponding Social Multiplier increases as the region's unemployment rate decreases. For the purposes of the model I assume that it attains its lower and higher values when the unemployment rate is around 1.75 and 0.5 times the normal rate respectively.

The values of the two indicators, obtained from equations 0200 and 0209 respectively, must be used as input to the Image Equation (p. 120) which generates the values for the Basic Image. According to their definition the range of values for both indicators is [0,2]. Ranges [0,1] ,however, are preferable for technical reasons because they ensure a co-domain -1,1 for the Basic Image. Equations 0222, 0223 transform the two indicators so as to acquire the required range. The transformed indicators , ALFA and BETA, are the inputs to the Image Equation. A real procedure – ROOT(ALFA,BETA,M,COMPVL) – has been added externally to the DYNAMO compiler in order to solve the Image Equation. The procedure – which is listed at the end of this section – has been programmed in ALGOL and does not appear in the final printout. A flow-chart outlining the solution procedure has been given in section 6.3.

Finally, equations 0224, 0225 define the Basic Image Multiplier or in other words a multiplier expressing the influence of Basic Image on the development of a city. For the purposes of the model a simple relationship has been adopted which is illustrated graphically in Figure 6.13.

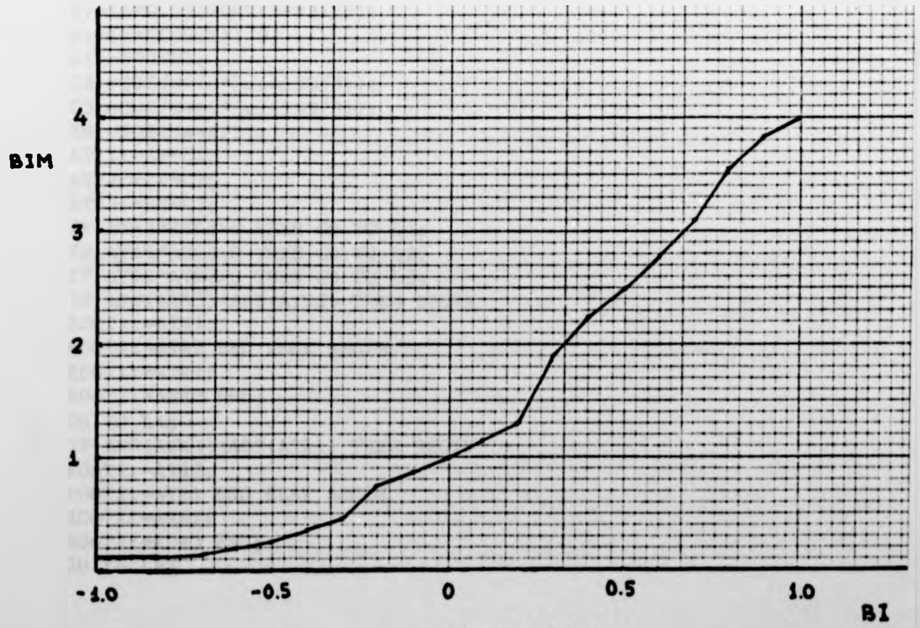

Figure 6.13

```
REAL PROCEDURE ROOT(ALFA,BETA,M,COMPVL); REAL ALFA,BETA,M,COMPVL;
   BEGIN
   REAL ALFO,BETO,T,A1,A,B,B1,D,Z,V,ATR1,ROOT1;
   REAL ATR2,ROOT2,S,W,C1,C2,C3,EN,ATR3;
   LABEL L4,L9;
   ALFO:=0.5;
   BETO:=0.5;
   T:=1/3;
   IF M<1 THEN BEGIN
   A:=M*(ALFA-ALFO)+(BETA-BETO);
   B:=(ALFA-ALFO)-M*(BETA-BETO) END ELSE BEGIN
   A:=(ALFA-ALFO)+(1/M)*(BETA-BETO);
   B:=(1/M)*(ALFA-ALFO)-(BETA-BETO) END;
   A1:=ABS(A);
   IF B<0 THEN BEGIN
   B1:=ABS(B);
   D:=(A1**2)/4+(B1**3)/27 END ELSE
   D:=(A1**2)/4-(B**3)/27;
   IF D>0 THEN BEGIN
   Z:= IF 0.5*A-SQRT(D)<0 THEN
     -(ABS(0.5*A-SQRT(D)))**T ELSE
          (0.5*A-SQRT(D))**T;
   V:= IF 0.5*A+SQRT(D)<0 THEN
     -(ABS(0.5*A+SQRT(D)))**T ELSE
          (0.5*A+SQRT(D))**T;
   ATR1:=Z+V;
   ROOT:=ATR1;
   COMPVL:=ATR1;
   GO TO L9; END ELSE IF D=0 THEN BEGIN
   Z:= IF A<0 THEN -(0.5*A1)**T ELSE (0.5*A)**T;
   ATR1:=2*Z;
   ATR2:=-Z;
   ROOT1:=ATR1;
   ROOT2:=ATR2;
   GO TO L4; END ELSE BEGIN
   LABEL L1,L2,L3;
   S:=(A*0.5)/SQRT(B**3/27);
   W:=(ARCCOS(S))/3;
   C1:=COS(W);
   C2:=COS(W+(2*3.14159/3));
   C3:=COS(W+(4*3.14159/3));
   EN:=SQRT(4*B/3);
   ATR1:=EN*C1;
   ATR2:=EN*C2;
   ATR3:=EN*C3;
   IF ATR2*ATR3>0 THEN GO TO L1;
   IF ATR1*ATR3>0 THEN GO TO L2;
   IF ATR1*ATR2>0 THEN GO TO L3;
L1: IF ABS(ATR3)<ABS(ATR2) THEN BEGIN
   ROOT1:=ATR1;
   ROOT2:=ATR2 END ELSE BEGIN
   ROOT1:=ATR1;
   ROOT2:=ATR3 END;
   GO TO L4;
L2: IF ABS(ATR3)<ABS(ATR1) THEN BEGIN
   ROOT1:=ATR2;
   ROOT2:=ATR1 END ELSE BEGIN
   ROOT1:=ATR2;
   ROOT2:=ATR3 END;
   GO TO L4;
```

```
L3: IF ABS(ATR1)<ABS(ATR2) THEN BEGIN
    ROOT1:=ATR3;
    ROOT2:=ATR2; END ELSE BEGIN
    ROOT1:=ATR3;
    ROOT2:=ATR1 END;
    GO TO L4; END;
L4: IF COMPVL>0 THEN
    ROOT:= IF ROOT1>0 THEN ROOT1 ELSE ROOT2 ELSE
    ROOT:= IF ROOT1>0 THEN ROOT2 ELSE ROOT1;
    GO TO L9;
L9: END;
```

The Basic Image Derivation Submodel, has been constructed to describe cities where the majority of economically active persons work and live within the politically fixed boundaries; however like the Cusp Location Submodel it may also be used without any modifications for the case of cities functioning within a wider commuter region.

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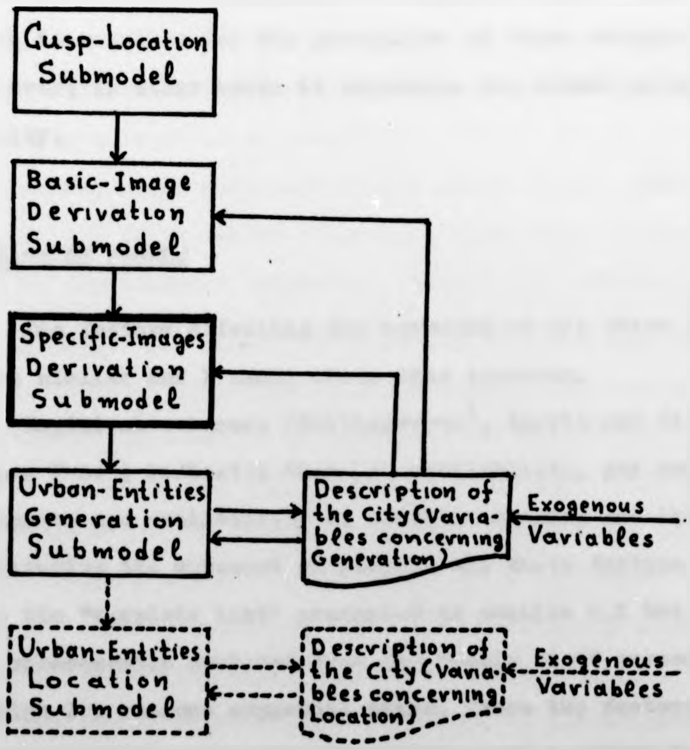
Chapter 7

Specific-Images Derivation Submodel

Figure 7.1 relates the derivation of the Specific Images to the rest of the model.



<u>Figure 7.1</u> Specific-Images Derivation submodel as part of the complete model

Potential movers in and out of a city divide into two groups people and industrial units; people are further divided into three groups according to their occupational status. Therefore, the proposed model distinguishes, in all, four groups of potential movers. The main factor influencing the Specific Images of all four groups is the Basic Image of the city. However, each group is also influenced by several other factors which it is my objective in the next two sections to discuss and quantify. In the course of this Chapter I shall be referring to the Specific Images of the city sometimes as "Real" and sometimes as "Perceived". The former term has been introduced for technical reasons and expresses the opinion a potential mover would have if he could instantly perceive and assess any changes that take place. The latter term represents the Specific Image "delayed" by the time which is required for the perception of those changes by the potential mover; in other words it expresses his actual opinion about a given city.

7.1 THE CASE OF PEOPLE

The factors affecting the movement of all three groups of people are similar and I shall study them together.

Empirical evidence (Cullingworth[1], Harris and Clausen[2], Hunter and Reid[3]) indicates that job availability, pay and promotion prospects and availability of suitable housing are the main factors influencing the movement of people. All three factors were included in the "complete list" presented in section 6.1 but the first two were subsequently excluded from the "basic list" presented in the same section for reasons explained there. Those two factors, however, when operating within the right framework exert a strong influence on the final choice of potential movers; in addition they may be used as negative control mechanisms to check the growth of a given city. Those two reasons justify their inclusion among the factors defining the Specific Image of a city as perceived by the various groups of people. Availability of suitable housing has already been included among the factors controlling the Basic Image and consequently its influence on the development of the city has been taken into account. At this point one may argue that since houses are divided into three groups, largely corresponding to the three groups of heads classified according to their income, a measure of housing availability for each particular group must also be introduced. The correspondence, however, between heads of families and housing units is not very strict. The model assumes that heads of any income group may occupy houses of the corresponding or lower group and under certain conditions houses of the immediately higher group also. Therefore, the information provided by the overall housing multiplier introduced in the previous chapter may be justifiably considered as covering all three groups of people. Finally, financial assistance is the last entity to be considered. Although generally not a factor of primary importance in the case of people it is nevertheless taken into account for technical reasons.

Job Availability: Job availability is one of the basic factors in modelling the movemen of population. The reasons for its exclusion from the "basic list" have been discussed in section 6.1. For the purposes of the model the job availability for each group of active employees is expressed as the ratio of the total number of economically active persons belonging to that group over the number of jobs available for them. Obviously a value of this ratio greater than the normal value indicates a significant job shortage while a value of it less than the normal indicates the existence of job vacancies in the city.

Pay and Promotion Prospects: Job availability is not the only concern of potential movers; employment conditions, i.e. wage levels and promotion prospects fare equally high in their list of preferences. The model generates the number of employees who move to the next higher occupational group during each period. Promotion however is a more general process which also covers upgrading within the same occupational group; hence a more comprehensive variable than the rate of inter-group movements is required for measuring it. New industries are generally considered as offering higher wages and better promotion prospects than any other type of industry. Therefore, for the purposes of the model pay and promotion prospects in a given city are measured indirectly in terms of an Industrial Composition Index. An industrial composition scale has been defined and the scores for New Mature and Declining Industrial Units are 2,1 and 0 points respectively. The average score for the entire industrial stock of a given city represents its Industrial Composition Index.

Financial Assistance: Financial assistance is not as important a factor as the previous two in influencing population movement. However, its inclusion is justified on the ground of its potential use as a control mechanism . For the purposes of the model a Tax Rate has been introduced and it is expressed as the amount payable per pound of rateable housing value. An increase in the level of external financial assistance results generally in a reduction of the required tax-rate. The weighting given to taxation in constructing the Specific Images for persons is very small.

Concluding this section I could say that of the three factors controlling the Specific Image of a city for the various groups of people, job availability and pay/promotion prospects exert a positive influence in the sense that they may "push" people into a city offering the right conditions. Taxation has a small "negative" effect if any, as it is more influential in stopping people from moving into a city with high rates rather than pushing them into another one with low rates.

7.2 THE CASE OF INDUSTRIES

Empirical evidence (Luttrell[4], Report on the Location of Industry[5], Rhodes and Khan[6], Sant[7], Townroe[8]) indicates that the main factors controlling industrial movement are availability of labour, quality of labour, financial assistance and availability of land for industrial expansion. All four factors appeared in the "complete list" of section 6.1 but the first three have not been included in the "basic list". Those three factors will now be used for the generation of the Specific Images as perceived by industrial units. Land availability has already been included in the "basic list" and it will not be used here again.

Quality of Labour: Quality of labour is one of the main factors in modelling industrial movement. Its exclusion from the basic list" has been discussed in section 6.1. A labour quality scale has been defined and the scores for the various types of economically active persons have been fixed. Professional and Skilled employees score 2 and 1.5 points respectively while Unskilled employees score no points. The average score for the entire workforce of a given city represents its Labour Quality Index.

The importance of labour quality is obviously diminishing if we assume that qualified employees who live outside the city may work in it. The model is constructed to deal primarily with people who both live and work in the city but the case of employees living within the city's commuter region is also discussed.

Availability of Labour: All the comments made about quality of labour apply equally well in this case also. For the purposes of the model availability of labour is expressed as the ratio of the total number of economically active persons over the number of jobs available for them. A value of this ratio greater than the normal indicates a relative abundance of available labour while a value of it less than the normal indicates shortage of labour in the city.

Financial Assistance: Financial assistance is a factor of potentially great importance for industrial movement. Whereas in the case of people its main effect was to aleviate hardship in depressed areas in the case of industries it may also provide positive inducements for movement. A tax-rate has also been introduced in this case as the amount payable per pound of rateable industrial unit value. Negative tax rates may in some cases be used as a way of modelling positive financial inducements.

7.3 MODELLING THE DERIVATION OF SPECIFIC IMAGES

Following the presentation of the factors controlling the Specific Images of a city, I shall now describe how they combine to give us the values of those Images as perceived by the various groups of potential movers. The model distinguishes between four groups of movers and I shall examine each of them separately.

7.3.1 Specific Image for Active Unskilled Heads

Figure 7.2 illustrates graphically the procedure followed for the derivation of the Specific Image as perceived by Active Unskilled Heads.

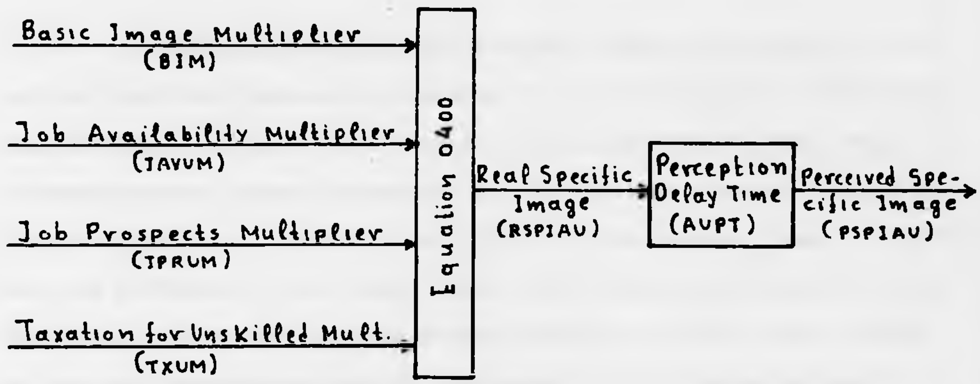


Figure 7.2

Derivation of Specific Image for Active Unskilled Heads

The following set of equations simulate the process shown in Figure 7.2. An alphabetical list of all the terms appearing in this section is given in Appendix 3. The same applies for the three remaining sections of this chapter.

```
0400  RSPIAU.K=EXP((1/4)(LOGN((BIM.K)(JAVUM.K)(JPRUM.K)(TXUM.K))))

0401  JAVUM.K=TABHL(JAVUMT,RUJR.K,0,2.25,0.25)
0402  JAVUMT*=0.32/0.50/0.65/0.90/1.00/1.15/1.30/1.45/1.59/1.59

0403  JPRUM.K=TABHL(JPRUMT,RICPIX.K,0,1.75,0.25)
0404  JPRUMT*=0.32/0.40/0.55/0.70/1.00/1.30/1.59/1.59

0405  TXUM.K=TABHL(TXUMT,1/RRPP.K,0,3.5,0.5)
0406  TXUMT*=0.32/0.92/1.00/1.02/1.05/1.10/1.40/1.59

0407  PSPIAU.K=PSPIAU.J+(DT/AUPT.J)(RSPIAU.J-PSPIAU.J)
```

Equation 0400 generates the Real Image of a given city for Active Unskilled Heads as a function of four multipliers representing the factors which have been considered as affecting it. The range standardisation formula described in the previous chapter is used in this case as well. The first multiplier is the dominant one. It expresses the influence of the Basic Image and it has been defined in section 6.4. Multiplication with unequal weights has again been chosen as the more appropriate way of combining the four terms because it underlines the dominance of the Basic Image without underestimating the significance of the remaining factors in certain specific cases. Such cases include slowly developing cities,which may gain the necessary momentum through the exogenous provision of jobs and the relaxation of financial burdens and also overgrown cities,whose further development may be checked through urban policies involving those factors.

Equations 0401-0406 define the multipliers used in eq. 0400. The general comments on the quantification of directly immeasurable variables and relationships made in the previous chapter apply in this case too.

Equations 0401,0402 and Figure 7.3 illustrate the effect of Job Availability on the Specific Image. The relationship used in this case is similar to that employed for the derivation of the Regional Social Multiplier. Job Availability Multiplier increases as unemployment rate decreases. For the purposes of the model I assume that it attains its maximum value when the chances of employment are about 2 times better than those in the normal city. Its minimum value on the other hand, corresponds to the case of a city where the chances of employment are more than 2 times worse than the chances in the normal city.

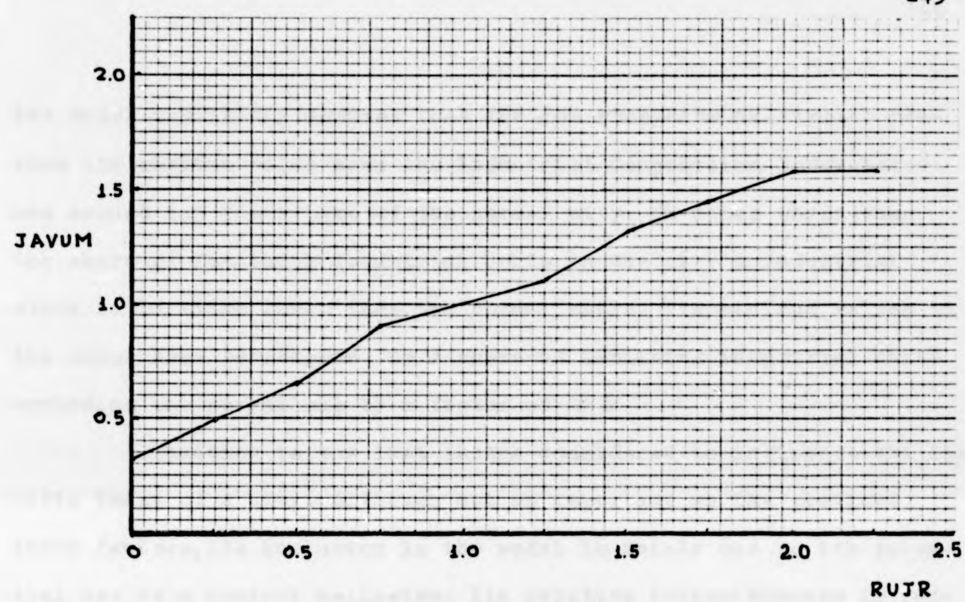


Figure 7.3

A similar relationship has been employed for modelling the influence of Job Prospects on the Specific Image (eqs. 0403, 0404; Figure 7.4).

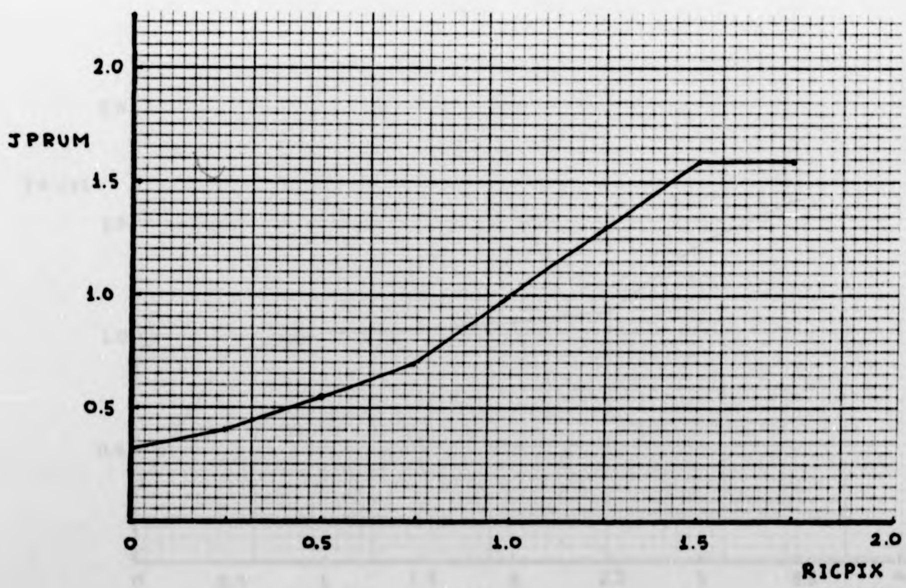


Figure 7.4

The model implicitly assumes that the Job Prospects Multiplier reaches its maximum value when the Industrial Composition Index becomes around 1.5 times that of the normal city; in other words,when the share of Declining Industrial Units in the city's industrial stock is 3-4 times lower than the normal share. Its minimum values on the other hand correspond to a share of Declining Industrial Units exceeding the normal one by a factor of 2-3

Taxation is the last factor considered to influence the Specific Image of a city. Although not as important as the previous three factors,its inclusion in the model is mainly due to its potential use as a control mechanism. Its relative insignificance is reflected by the fact that it is only under extreme conditions that the Taxation Multiplier plays any important part in the definition of the Specific Image (eqs. 0405, 0406; Figure 7.5). Note that the Taxation Multiplier as defined above increases as the rate per pound decreases.

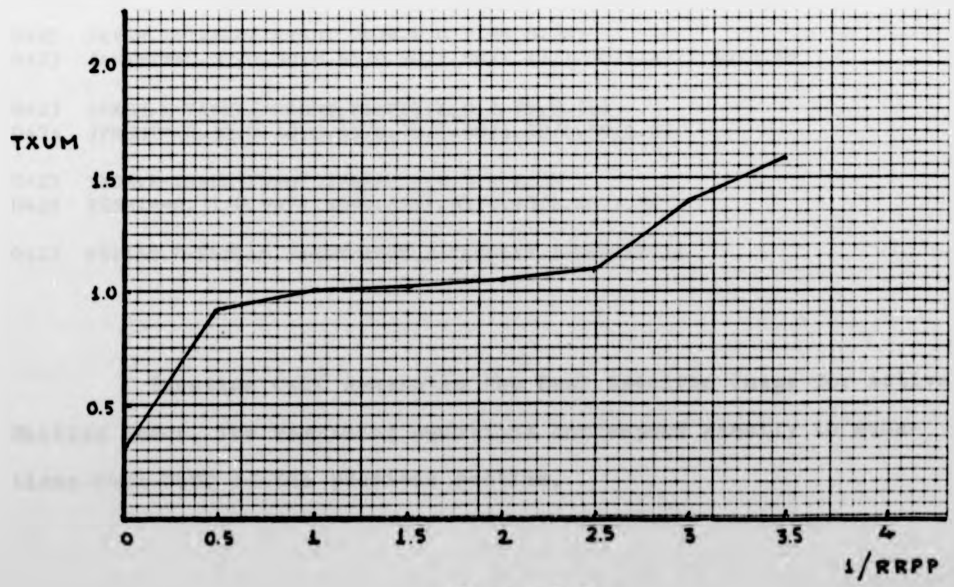


Figure 7.5

Finally, equation 0407 generates the Specific Image of the city as perceived by Active Unskilled Heads. As I have mentioned already, Perceived Specific Image is essentially the Real one delayed by the period which is required for the perception and assessment of any relevant changes by the potential movers. The perception time for Active Unskilled Heads — as indeed for any group of movers — is given exogenously; obviously, the shorter the perception time the smaller the difference between Real and Specific Image at the same point in time.

7.3.2 Specific Image for Active Skilled Heads

Modelling the derivation of the Specific Image as perceived by Active Skilled Heads is done in the way described for the case of Unskilled Heads and it is simulated by the following set of equations.

```
0420  RSPIAS.K=EXP((1/4)(LOGN((BIM.K)(JAVSM.K)(JPRSM.K)(TXSM.K))))

0421  JAVSM.K=TABHL(JAVSMT,RSJR.K,0,2.25,0.25)
0422  JAVSMT*=0.32/0.50/0.65/0.90/1.00/1.15/1.30/1.45/1.59/1.59

0423  JPRSM.K=TABHL(JPRSMT,RICPIX.K,0,1.75,0.25)
0424  JPRSMT*=0.32/0.40/0.55/0.70/1.00/1.30/1.59/1.59

0425  TXSM.K=TABHL(TXSMT,1/RRPP.K,0,3.5,0.5)
0426  TXSMT*=0.32/0.92/1.00/1.02/1.05/1.10/1.40/1.59

0427  PSPIAS.K=PSPIAS.J+(DT/ASPT.J)(RSPIAS.J-PSPIAS.J)
```

Equation 0420 generates the Real Specific Image for Active Skilled Heads. The remaining equations correspond exactly to equations 0401-0407 of the previous section.

7.3.3 Specific Image for Active Professional Heads

The Specific Image of the city as perceived by Active Professional Heads is defined in a way very similar to that described in the previous two sections. Its derivation is simulated by the following set of equations:

```
0440  RSPIAP.K=EXP((1/4)(LOGN((BIM.K)(JAVPM.K)(JPRPM.K)(TXPM.K))))

0441  JAVPM.K=TABHL(JAVPMT,RPJR.K,0,2.25,0.25)
0442  JAVPMT*=0.32/0.50/0.65/0.90/1.00/1.15/1.30/1.45/1.59/1.59

0443  JPRPM.K=TABHL(JPRPMT,RICPIX.K,0,1.75,0.25)
0444  JPRPMT*=0.32/0.40/0.55/0.70/1.00/1.30/1.59/1.59

0445  TXPM.K=TABHL(TXPMT,1/RRPP.K,0,3.5,0.5)
0446  TXPMT*=0.32/0.92/1.00/1.02/1.05/1.10/1.40/1.59

0447  PSPIAP.K=PSPIAP.J+(DT/APPT.J)(RSPIAP.J-PSPIAP.J)
```

All equations presented above correspond exactly to those of the previous section.

7.3.4 Specific Image for New Industries

The last three sections were concerned with the perception of the city's Image by various groups of potential employees. The present sector covers the derivation of the Specific Image as perceived by the employers.

Figure 7.6 illustrates the derivation procedure graphically.

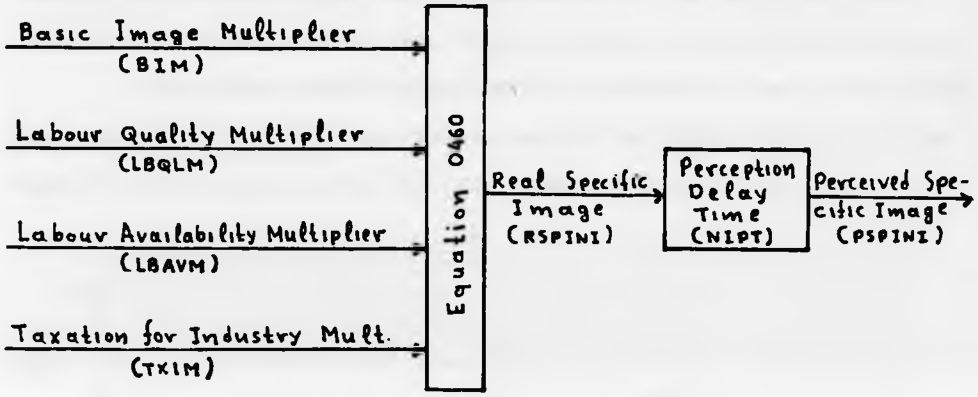


Figure 7.6

Derivation of Specific Image for New Industrial Units

The following set of equations simulate the modelling procedure illustrated in Figure 7.6.

```
0460  RSPINI.K=EXP((1/4)(LOGN((BIM.K)(LBQLM.K)(LBAVM.K)(TXIM.K))))

0461  LBQLM.K=TABHL(LBQLMT,RWCPIX.K,0,1.75,0.25)
0462  LBQLMT*=0.32/0.45/0.35/0.60/1.00/1.45/1.59/1.59

0463  LBAVM.K=TABHL(LBAVMT,1/RTJR.K,0,4,0.5)
0464  LBAVMT*=0.32/0.85/1.00/1.30/1.59/1.35/1.10/0.55/0.32

0465  TXIM.K=TABHL(TXIMT,1/RRPP.K,0,3.5,0.5)
0466  TXIMT*=0.32/0.87/1.00/1.05/1.10/1.15/1.45/1.59

0467  PSPINI.K=PSPINI.J+(DT/NIPT.J)(RSPINI.J-PSPINI.J)
```

Although the movers in this case are not people but industrial units the same procedure is followed. Equation 0460 is struc-

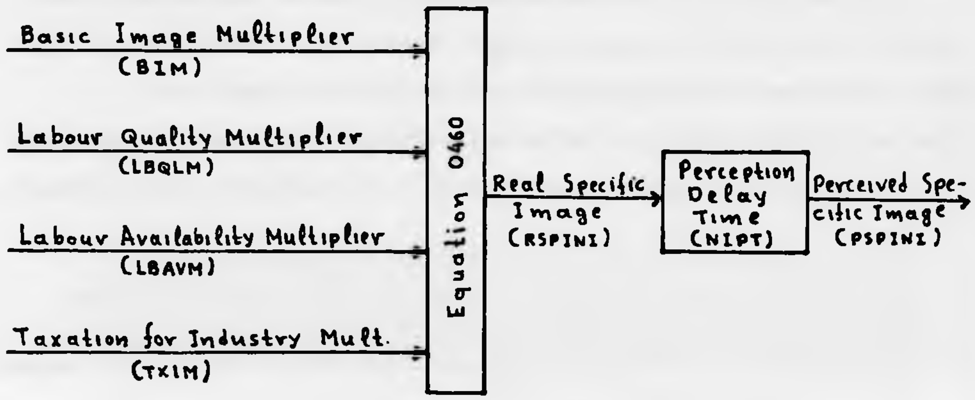


Figure 7.6

Derivation of Specific Image for New Industrial Units

The following set of equations simulate the modelling procedure illustrated in Figure 7.6.

```
0460  RSPINI.K=EXP((1/4)(LOGN((BIM.K)(LBQLM.K)(LBAVM.K)(TXIM.K))))

0461  LBQLM.K=TABHL(LBQLMT,RWCPIX.K,0,1.75,0.25)
0462  LBQLMT*=0.32/0.45/0.35/0.60/1.00/1.45/1.59/1.59

0463  LBAVM.K=TABHL(LBAVMT,1/RTJR.K,0,4,0.5)
0464  LBAVMT*=0.32/0.85/1.00/1.30/1.59/1.35/1.10/0.55/0.32

0465  TXIM.K=TABHL(TXIMT,1/RRPP.K,0,3.5,0.5)
0466  TXIMT*=0.32/0.87/1.00/1.05/1.10/1.15/1.45/1.59

0467  PSPINI.K=PSPINI.J+(DT/NIPT.J)(RSPINI.J-PSPINI.J)
```

Although the movers in this case are not people but industrial units the same procedure is followed. Equation 0460 is structurally equivalent to the corresponding one of the previous three sections and generates the Real Specific Image for Industrial Units.

Equations 0461-0466 define the multipliers used in eq. 0460. Equations 0461 and 0462 describe the effect of Labour Quality on the Specific Image and Figure 7.7 illustrates it graphically.

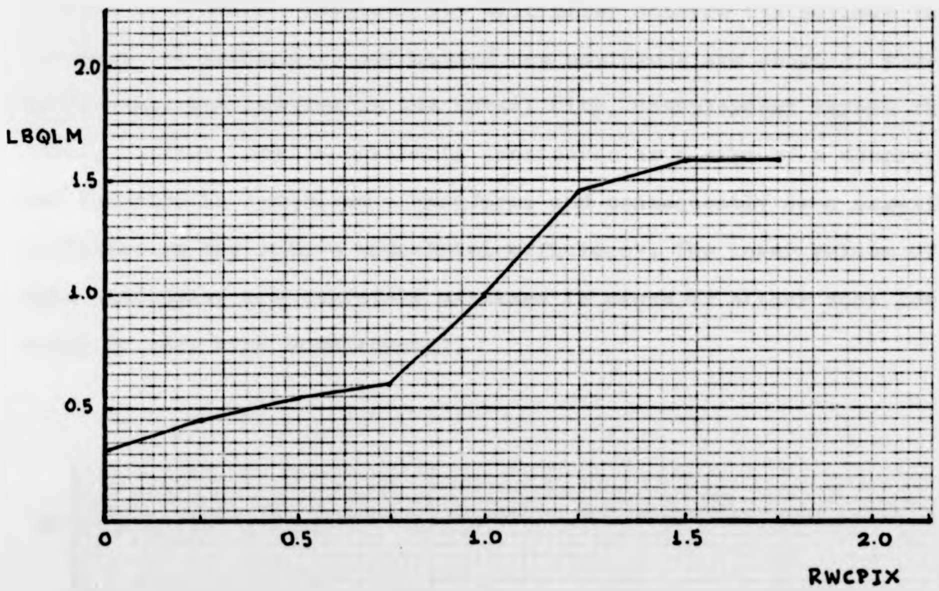


Figure 7.7

The Labour Quality Multiplier increases with the Relative Workforce Composition Index. It reaches its maximum value when the Composition Index is around 1.5 times that of the normal city; in other words, when the share of unskilled employees among the city's total economically active populationis appn3 times less than the normal share. Its minimum value,on the other hand,corresponds to a share of unskilled employees exceeding the normal one by a factor of 2.

Unemployment, a factor influencing population movement, is also considered as a factor affecting industrial movement. In this case however, unemployment rate higher than normal is generally considered as favourable condition. Equations 0463, 0464 and Figure 7.8 illustrate the effect of unemployment on industrial movement. The relationship used in this case is similar to that employed for the derivation of the Regional Industrial Multiplier. The model implicitly assumes that Labour Availability Multiplier attains its maximum value when the chances of recruiting new employees are about 2 times better than the chances in the normal city. Unemployment beyond this level, however, may be generally considered as a sign of a dispirited and potentially troublesome workforce and consequently as a negative influence on the city's industrial efficiency. The lower values of this multiplier are therefore attained in cases of either very low rates or very high unemployment.

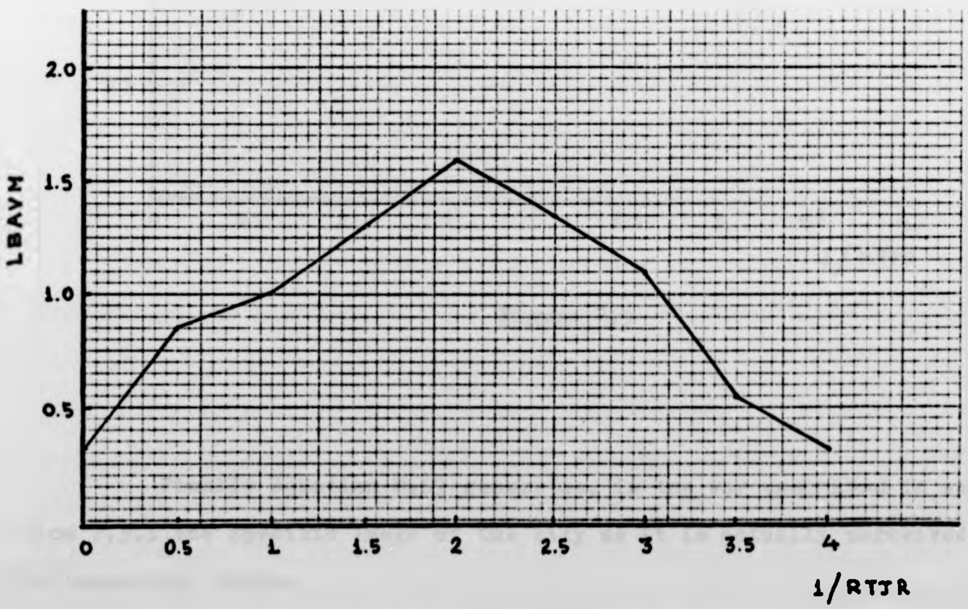


Figure 7.8

Although more important than in the case of people,taxation is still a factor of lesser significance than the previous two; this is indeed reflected in the way the Taxation Multiplier influences the Specific Image (eqs. 0465, 0466, Figure 7.9). Note that in this case also the Taxation Multiplier,as defined above,increases as the rate per pound decreases. Equations 0465, 0466 can be modified easily so as to include negative tax rates. Such rates may be used in some cases as a way of modelling the exogenous provision of positive financial inducements.

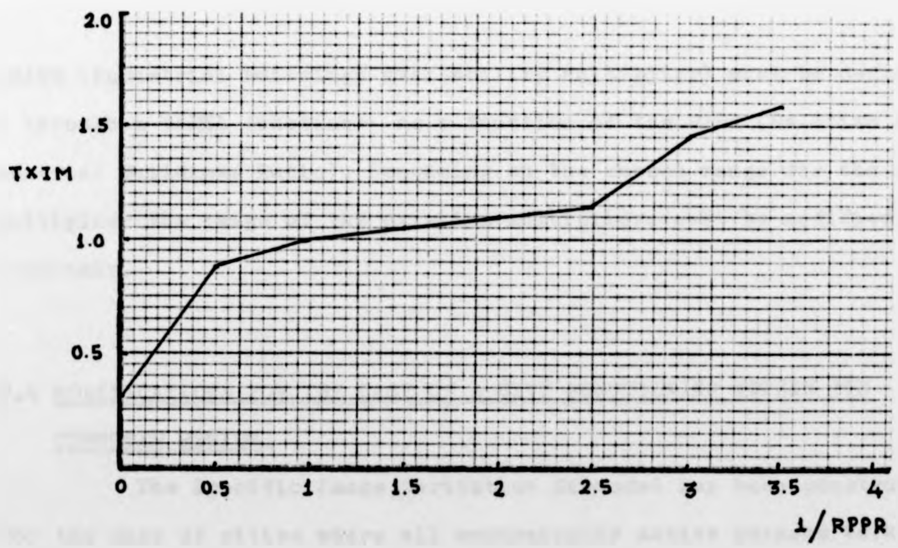


Figure 7.9

Finally equation 0467 generates, in the way described in section 7.3.1,the Specific Image of the city as it is actually perceived by Industrial Units.

For major part of the period covered by the model industrial buildings have been built by the Private Sector in response to demand.

Hence availability of industrial buildings has been treated as only a limiting factor in the generation of industrial activity and it has not been included among the variables influencing the Specific Image of the city. In recent years, however, the provision of industrial buildings has been increasingly used as a positive inducement. Its inclusion in the model,in this capacity,requires a slight modification of equation 0460 as follows:

RSPINI.K= EXP((1/5)(LOGN((BIM.K)(LBQLM.K)(LBAVM.K)(TXIM.K)(IBAVM.K))))

IBAVM (Industrial Buildings Availability Multiplier) must be defined – through a TABHL function – as a function of the RIBR (Relative Industrial Buildings Ratio). Depending on the chosen range for the new multiplier the range of the existing multipliers must be modified accordingly.

7.4 MODIFICATIONS FOR THE CASE OF A CITY FUNCTIONING WITHIN ITS COMMUTER REGION.

The Specific Image Derivation Submodel has been constructed for the case of cities where all economically active persons work and live within the politically fixed boundaries. However it may also be used for the case of cities functioning within a wider commuter region if the following modifications are introduced.

Modifications in Modelling Population Movement. When people living within the city boundaries can be employed outside them the factors of job availability and job prospects within the city itself decline in importance. This may be introduced into the model by modifying accordingly the TABLE functions expressing the relationship between

Job Ratio/Job Availability Multiplier and Industrial Composition/Job Prospects Multiplier.

Modifications in Modelling Industrial Movement. When industrial units located within the city boundaries can recruit employees from outside the city the factors of labour availability and labour quality within the city itself become less critical. This may be taken into account by modifying the TABLE functions describing the relationship between Job Ratio/ Labour Availability Multiplier and Workforce Composition Index/Labour Quality Multiplier.

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2. HARRIS,A.I. and CLAUSEN,R. Government Social Survey. Labour Mobility in Great Britain 1953-63, London, 1966.
3. HUNTER,L. and REID,G. Urban Worker Mobility. OECD, Paris, 1968.

Chapter 8

Urban-Entities Generation Submodel

Attraction of people and industries is considered as a function of the Specific Image of the city as perceived by the various groups of potential movers. Specific Images, however, are not absolute but relative measures of a city's attractiveness. The basis of comparison are the corresponding images of the hypothetical normal city. For the purposes of the model, the normal city is considered —as explained in Chapter 6— as the average of eighteen cities spread throughout England and Wales and it is taken to represent the average of all English cities. The model implicitly assumes that the Basic and Specific Images of the normal city are equal to 1.

Following the derivation of the Specific Images I shall now describe how the model uses them in order to generate changes in the stocks of people, industrial units and other entities related to them. Figure 8.1 relates the Urban Entity Generation Submodel with the rest of the model.

For facilitating its presentation the Entity Generation Submodel has been divided into 12 sectors on the basis of the main enti-

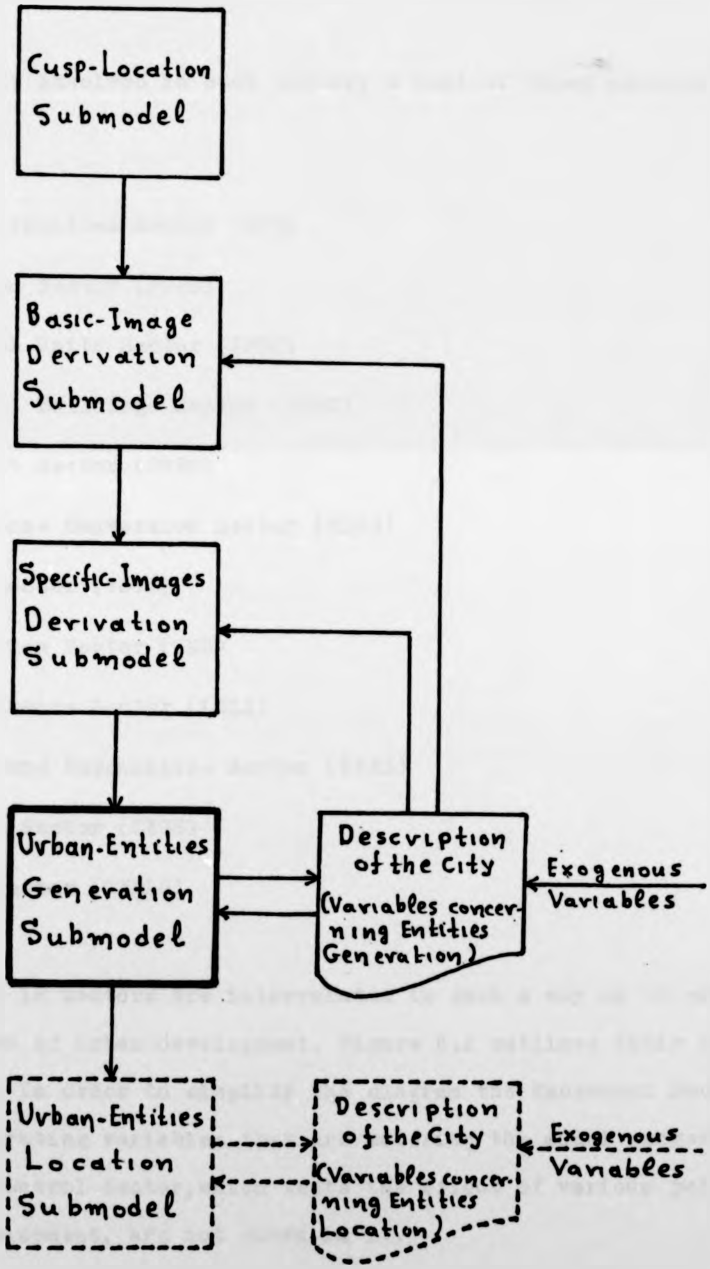

Figure 8.1

Urban-entities generation submodel as part of the complete model

ty or activity involved in each sector; a list of those sectors is given below:

1. Heads of Families Sector (HFS)
2. Population Sector (POPS)
3. Industrial Units Sector (INUS)
4. Industrial Buildings Sector (INBS)
5. Employment Sector (EMPS)
6. Skill-Income Conversion Sector (SICS)
7. Housing Sector (HOUS)
8. Construction Sector (CNS)
9. Land Clearance Sector (LCLS)
10. Taxation and Expenditure Sector (TEXS)
11. Exogenous Sector (EXGS)
12. Control Sector (CTRLS)

The 12 sectors are interrelated in such a way as to simulate the process of urban development. Figure 8.2 outlines their interrelationship. In order to simplify the diagram the Exogenous Sector, which is generating variables that are entering the model exogenously, and the Control Sector, which tests the effect of various policies on urban development, are not shown in it.

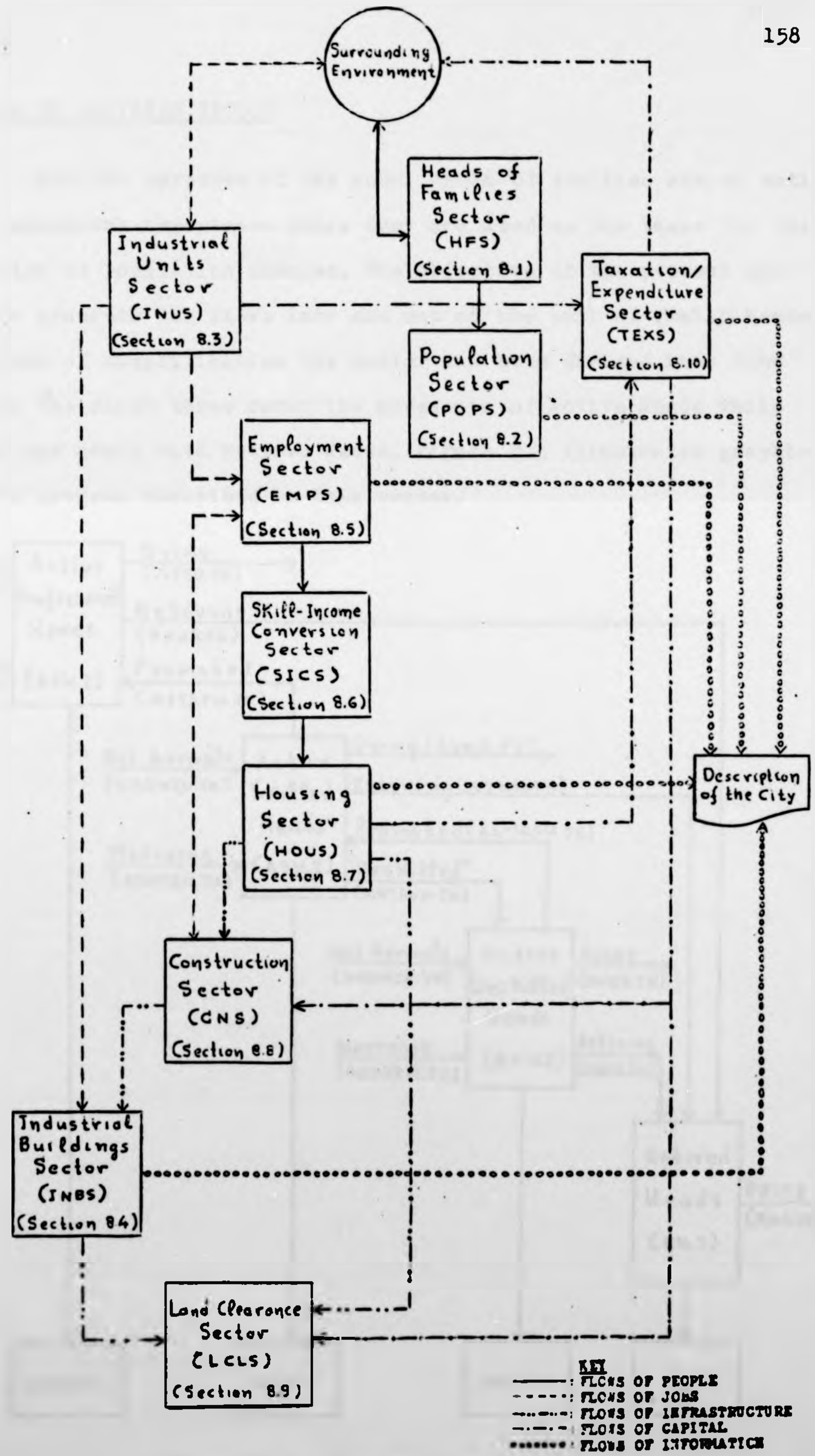

Figure 8.2 Sectors of the Urban Entities Generation Submodel

8.1 HEADS OF FAMILIES SECTOR

For the purposes of the model Heads of families are an entity of fundamental importance since they are used as the basis for the calculation of population changes. The objective of the present sector is to generate the flows into and out of the pool of family Heads. For reasons of simplification the sector has been divided into four sections: the first three cover the movements of Active Heads while the last one deals with Retired Heads. Figure 8.3 illustrates graphically the process described in this sector.

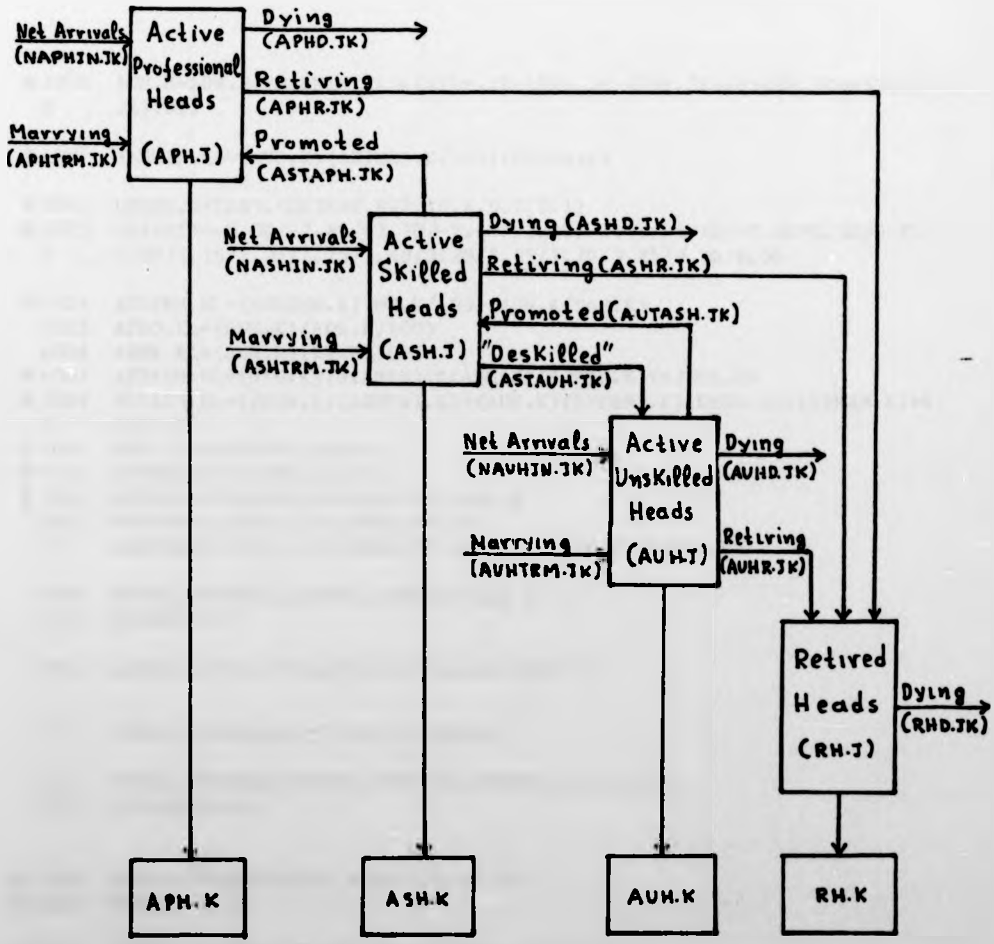

Figure 8.3 Heads of Families Sector

The set of equations expressing the movements of each type of family Heads are presented and analysed below:

8.1.1 Active Unskilled Heads

The following set of equations simulate the movement of Active Unskilled Heads. The basic equations are marked by an asterisk and they are discussed below. An alphabetical list of the terms appearing in this section is given in Appendix 3. The same applies for all sectors which will be presented in this Chapter.

```
*1000  AUH.K=AUH.J+(NAUHIN.JK+AUHTRM.JK-AUHD.JK-AUHR.JK-AUTASH.JK+ASTAUH.
 X     JK)(DT)

*1001  NAUHIN.KL=(AUH.K)(AHINRN.K/100)(UHINM.K)

*1002  UHINM.K=TABHL(UHINMT,PSPIAU.K,0,2,0.1)
*1003  UHINMT*=-3.00/-2.85/-2.70/-2.60/-2.40/-1.60/-1.40/-0.40/0.30/0.85/
 X     1.00/1.15/1.35/1.75/2.40/3.20/3.55/3.70/3.85/3.90/4.00

*1004  AUHTRM.KL=(MNHEMR.K)(MR.K/100)(AUH.K/TAH.K)
 1005  AUHD.KL=(AUH.K)(ADR.K/100)
 1006  AUHR.KL=(AUH.K)(RR.K/100)
*1007  ASTAUH.KL=(DIU.K)(DIABRN)(DIABM.K)(SJPIU.K)(SJVCM.K)
*1008  AUTASH.KL=((AUH.K)(AUTRN1.K)+(AUH.K)(AUTRN2.K)(DMSM.K))(STRAM.K)+U
 X     TRPG.K
*1009  AUTRN1.K=EXSTUH.K/AUH.K
*1010  AUTRN2.K=EXSTPH.K/AUH.K
*1011  AUTRN.K=(EXSTPH.K+EXSTUH.K)/AUH.K
 1012  EXSTPH.K=(APH.K)(PJINRN.K/100)
 1013  EXSTUH.K=(DIU.K)(DIABRN)(DIABM.K)(SJPIU.K)(SJVCM.K)

 1014  SJVCM.K=TABHL(SJVCMT,1/SNCJR.K,0,1,1)
 1015  SJVCMT*=0/1

 1016  SNCJR.K=(TIU.K)(SJPIU.K)/(TAS.K-SOCCJ.K)

 1017  SOCCJ.K=(TEMP.K)(0.065)(CJOCM.K)

 1018  CJOCM.K=TABHL(CJOCMT,TCNRFS.K/TCNRN.K,0,10,10)
 1019  CJOCMT*=0/10

*1020  DMSM.K=TABHL(DMSMT,RSJR.K,0,10,10)
*1021  DMSMT*=0/10

*1022  STRAM.K=TABHL(STRAMT,RSFR.K/RSJR.K,0,1,1)
*1023  STRAMT*=0/1
```

Equation 1000 is the central equation of this sector and accumulates the flows into and out of the pool of Active Unskilled Heads. The remaining equations analyse each one of the flows.

Equation 1001 computes the net inflow of Active Unskilled Heads while equations 1002 and 1003 generate the net inflow multipli-

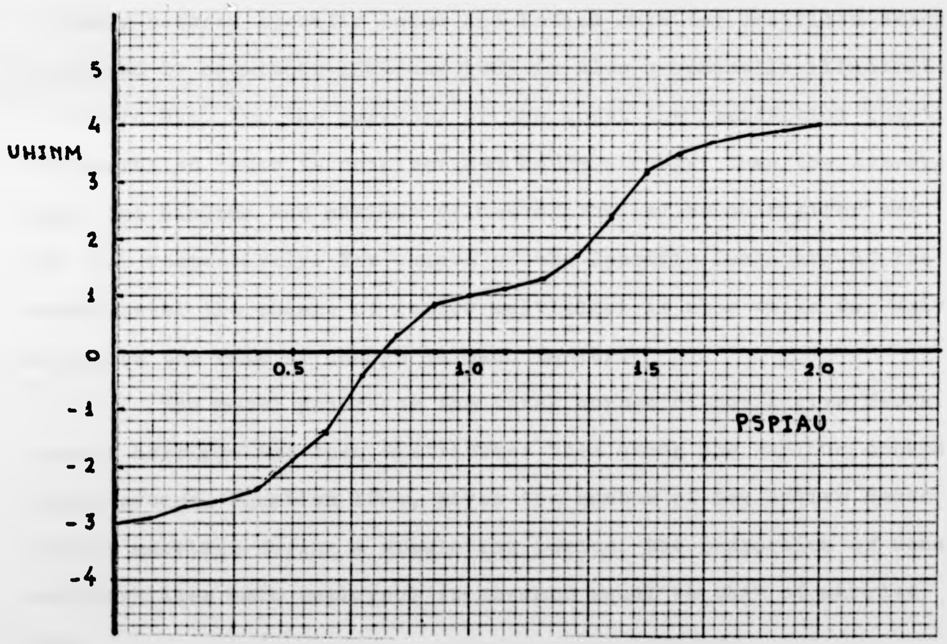

Figure 8.4

er. This multiplier is obviously a function of the corresponding Specific Image. For the purposes of the model the Specific Image of a city as perceived by prospective unskilled movers — and indeed by any group of potential movers — has been taken to vary from 0 through the normal value of 1 to a maximum of 2 . On the other hand evidence presented in Appendix 2 suggests that the net inflow rate of Active Heads varies from a minimum of -4 times the normal value to a maxi-

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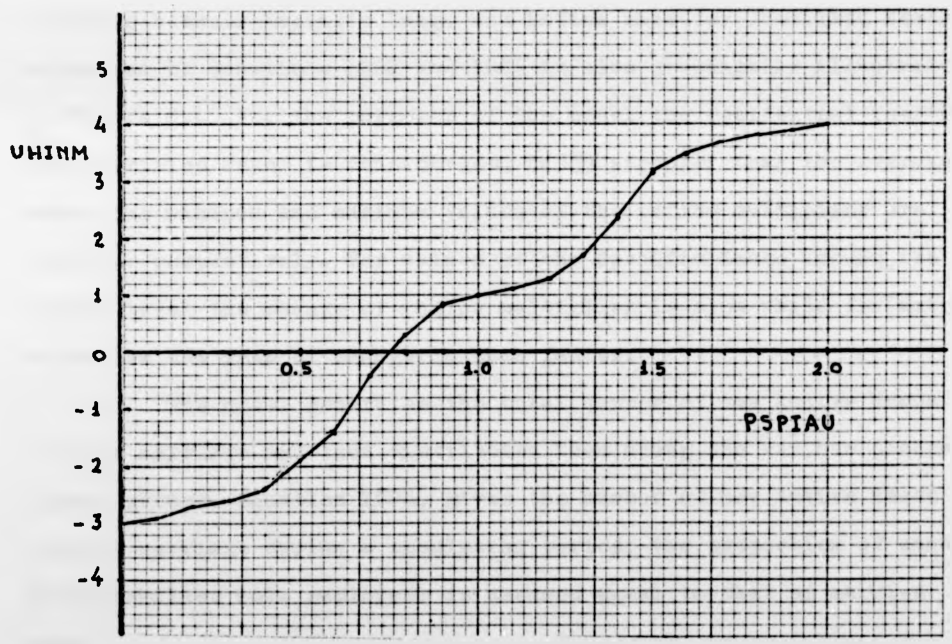

Figure 8.4

er. This multiplier is obviously a function of the corresponding Specific Image. For the purposes of the model the Specific Image of a city as perceived by prospective unskilled movers — and indeed by any group of potential movers — has been taken to vary from 0 through the normal value of 1 to a maximum of 2 . On the other hand evidence presented in Appendix 2 suggests that the net inflow rate of Active Heads varies from a minimum of -4 times the normal value to a maximum of +5 times the normal value. This variation however, applies to the average inflow rate for heads of all occupational groups. Empirical evidence suggests that the power of residential inertia is highest among unskilled employees. Therefore the average net inflow rate must be slightly modified so as to take into account the limited response of Unskilled Heads to changes of the Specific Image. The exact relationship between Specific Image and inflow rate for Unskilled Heads, expressed by equations 1002 and 1003 is also graphically illustrated in Figure 8.4. For the purposes of the model the residential inertia for Unskilled Heads is consideredup to 15% stronger than the average; hence the minimum and maximum values of the inflow multiplier are and -3,4 respectively. For values of the Specific Image around the normal level the change of inflow multiplier is slow while for extreme values the rate of change is much faster.

The model generates the total number of new Active Heads through marriage and then distributes them among the various occupational groups. Equation 1004, gives the number of new Active Heads through marriage during a simulation period; the proportion of unmarried unskilled male employees is assumed equal to that of married ones.

A number of skilled workers occupied in declining industries "loose" their skill when the industries die; equation 1007 generates this number during each simulaton period. On the other hand, a training process has been included in this sector and equation 1008 generates the number of Unskilled Heads acquiring skilled status. The model assumes that the normal training rate is such as to allow a city to replace any "deskilled" employees and also to satisfy the changing industrial manpower requirements (eqs 1009-1011). The achieved level of training (eq. 1008), is a function of the normal training rate but it also depends on the demand for skilled employees and the availability of skilled trainers. Demand is the primary influence. The relation between demand —expressed as the number of available jobs over the number of prospective employees— and the training needs are taken as simply proportional (Eqs 1020,1021 and Figure 8.5).

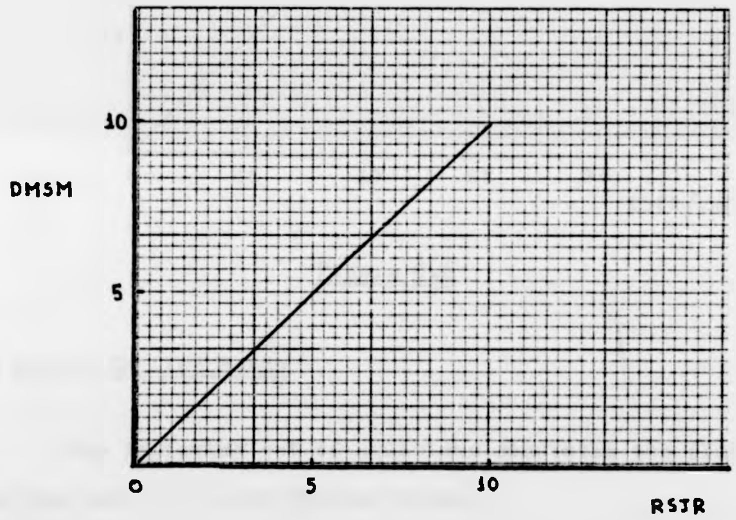

Figure 8.5

The satisfaction of all training requirements however, is subject to the availability of skilled trainers, expressed for the purposes of the model as the proportion of skilled employees in the total workforce. As long as enough skilled trainers are available, the set target derived as a function of the demand for skilled employees is achieved. In the opposite case,the training requirements are only partially satisfied. The effect of trainers' availability on the training levels is described by equations 1022, 1023 and illustrated by Figure 8.6.

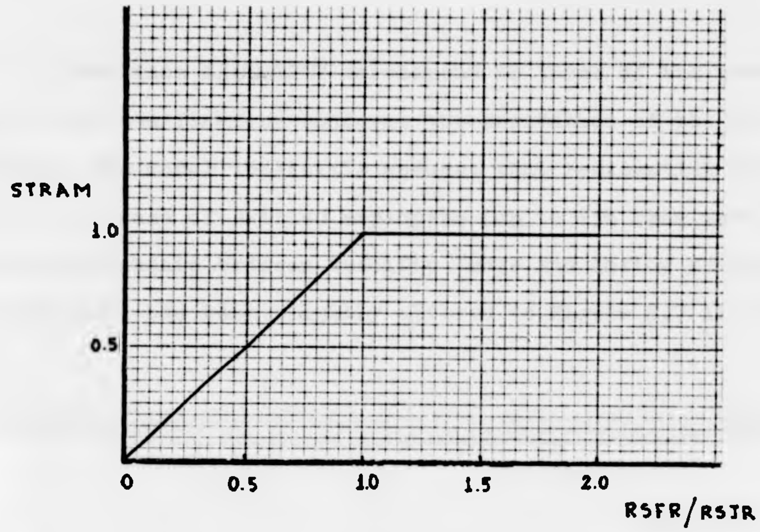

Figure 8.6

8.1.2 Active Skilled Heads

The following set of equations simulates the flows into and out of the pool of Active Skilled Heads.

```
 1200  ASH.K=ASH.J+(NASHIN.JK+ASHTRM.JK+AUTASH.JK-ASHD.JK-ASHR.JK-ASTAUH.
 X     JK-ASTAPH.JK)(DT)

 1201  NASHIN.KL=(ASH.K)(AHINRN.K/100)(SHINM.K)

*1202  SHINM.K=TABHL(SHINMT,PSPIAS.K,0,2,0.1)
*1203  SHINMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-2.60/-2.40/-0.90/0.10/0.75/
 X     1.00/1.25/1.65/2.25/3.00/3.80/4.25/4.50/4.80/4.90/5.00

 1204  ASHTRM.KL=(MNHEMR.K)(MR.K/100)(ASH.K/TAH.K)
 1205  ASHD.KL=(ASH.K)(ADR.K/100)
 1206  ASHR.KL=(ASH.K)(RR.K/100)
 1207  ASTAPH.KL=(ASH.K)(ASTRN.K)(ASTRM.K)+STRPG.K
*1208  ASTRN.K=EXSTPH.K/ASH.K
 1209  ASTRM.K=(DMPM.K)(PTRAM.K)

*1210  DMPM.K=TABHL(DMPMT,RPJR.K,0,10,10)
*1211  DMPMT*=0/10

*1212  PTRAM.K=TABHL(PTRAMT,RPFR.K/RPJR.K,0,1,1)
*1213  PTRAMT*=0/1
```

Equations 1200-1207 correspond to those of the previous sector; the only modification concerns the derivation of the net inflow multiplier. The model implicitly assumes that residential inertia is weaker in the case of skilled employees (up to 15% less than the average) and the relationship between Specific Image and inflow multiplier (eqs 1202,1203) has been slightly altered as Figure 8.7 illustrates.

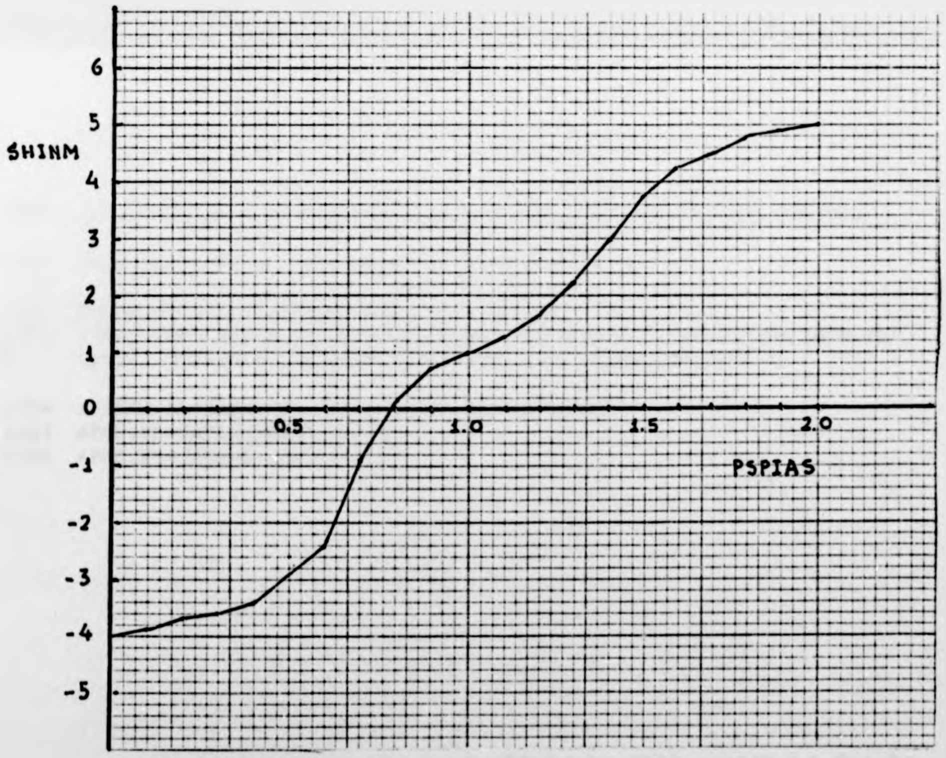

Figure 8.7

Equation 1208 generates the normal training rate for skilled employees. As in the case of unskilled employees the achieved level of training (eq. 1207) is a function of the normal training rate (eq 1208) but it also depends on the demand for professional employees (eqs 1210,1211) and the availability of professional trainers (eqs 1212, 1213).

8.1.3 Active Professional Heads

The following set of equations generate the movement of Active Professional Heads.

```
1400   APH.K=APH.J+(NAPHIN.JK+APHTRM.JK+ASTAPH.JK-APHD.JK-APHR.JK)(DT)

1401   NAPHIN.KL=(APH.K)(AHINRN.K/100)(PHINM.K)

1402   PHINM.K=TABHL(PHINMT,PSPIAP.K,0,2,0.1)
1403   PHINMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-2.60/-2.40/-0.90/0.10/0.75/
X       1.00/1.25/1.65/2.25/3.00/3.80/4.25/4.50/4.80/4.90/5.00

1404   APHTRM.KL=(MNHEMR.K)(MR.K/100)(APH.K/TAH.K)
1405   APHD.KL=(APH.K)(ADR.K/100)
1406   APHR.KL=(APH.K)(RR.K/100)
```

The smaller number of equations in this sector is due to the omission of all equations concerning training. Professionals belong to the highest occupational group and consequently training is irrelevant in this case. The existing equations, however, are structurally equivalent to the correspondning ones of the previous sections.

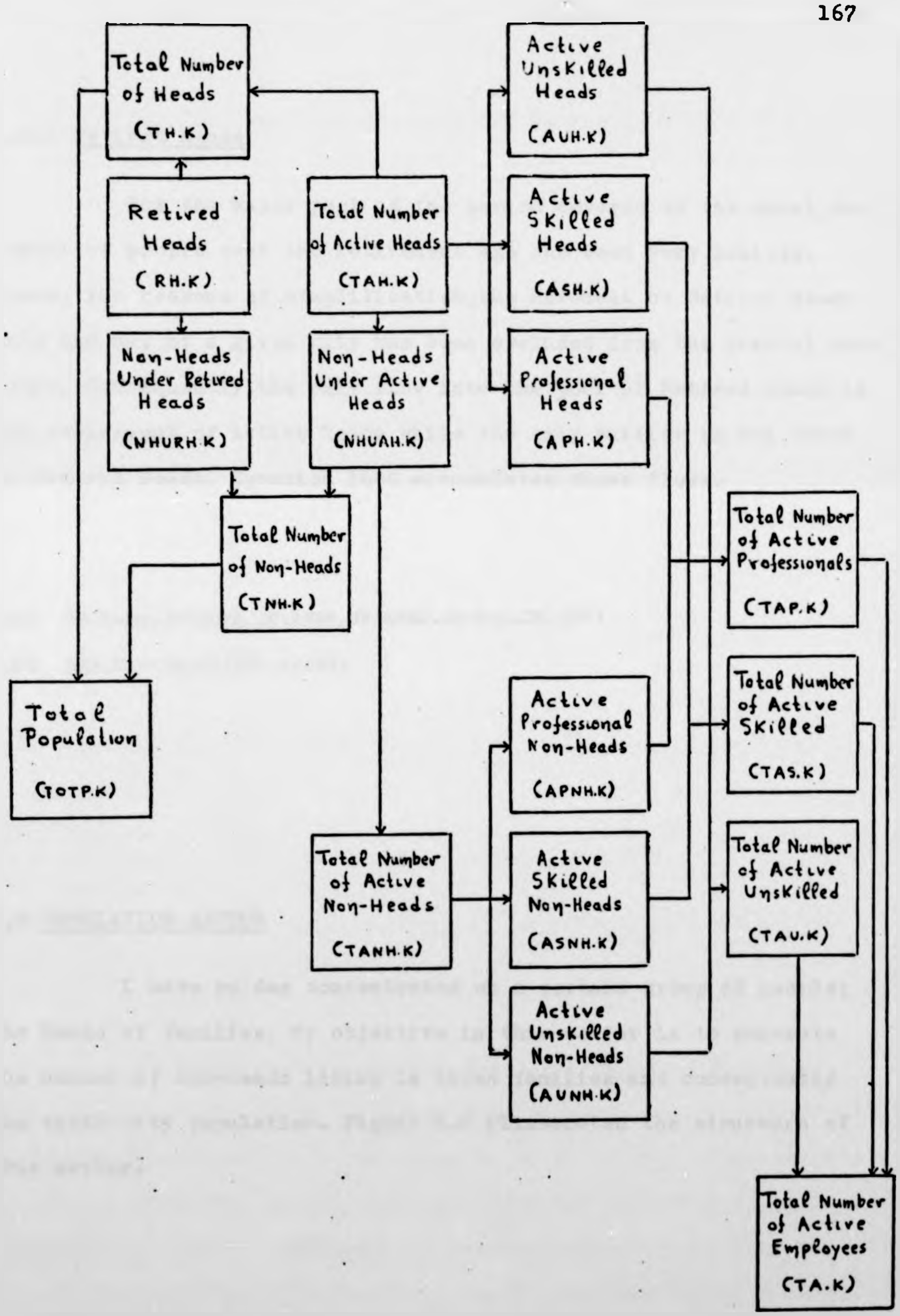

Figure 8.8

Population Sector

8.1.4 Retired Heads

For the major part of the period covered by the model, movement of people over the retirement age has been very limited. Hence, for reasons of simplification, the movement of Retired Heads into and out of a given city has been excluded from the present analysis. Consequently, the only flow into the pool of Retired Heads is the retirement of Active Heads while the only outflow is the death of Retired Heads. Equation 1600 accumulates those flows.

```
*1600  RH.K=RH.J+(AUHR.JK+ASHR.JK+APHR.JK-RHD.JK)(DT)
 1601  RHD.KL=(RH.K)(RDR.K/100)
```

8.2 POPULATION SECTOR

I have so far concentrated on a certain group of people; the Heads of families. My objective in this sector is to generate the number of non-heads living in those families and consequently the total city population. Figure 8.8 illustrates the structure of this sector.

The following set of equations simulate the process shown in Figure 8.8.

```
*2000  NHURH.K=(RH.K)(RFS-1)
*2001  NHUAH.K=(TAH.K)(AFS.K-1)
*2002  TANH.K=(TAH.K)(NHEAPF.K)
*2003  AUNH.K=(TANH.K)(AUH.K/TAH.K)
*2004  ASNH.K=(TANH.K)(ASH.K/TAH.K)
*2005  APNH.K=(TANH.K)(APH.K/TAH.K)
*2006  MNHEMR.K=(NHUAH.K-TCUSLA.K-TMRFM.K)(MPR.K/100)
 2007  TCUSLA.K=(TAH.K)(CPAF.K)
 2008  TMRFM.K=TAH.K
*2009  TAHTRM.KL=(MNHEMR.K)(MR.K/100)
 2010  TAH.K=AUH.K+ASH.K+APH.K
 2011  TH.K=TAH.K+RH.K
 2012  TNH.K=NHUAH.K+NHURH.K
 2013  TOTP.K=TH.K+TNH.K
 2014  TAU.K=AUH.K+AUNH.K
 2015  TAS.K=ASH.K+ASNH.K
 2016  TAP.K=APH.K+APNH.K
 2017  TA.K=TAH.K+TANH.K

 2018  UFR.K=TAU.K/TA.K
 2019  RUFR.K=UFR.K/UFRN.K
 2020  SFR.K=TAS.K/TA.K
 2021  RSFR.K=SFR.K/SFRN.K
 2022  PFR.K=TAP.K/TA.K
 2023  RPFR.K=PFR.K/PFRN.K
 2024  WCPIX.K=((TAP.K)(2.0)+(TAS.K)(1.5)+(TAU.K)(0.0))/TA.K
 2025  RWCPIX.K=WCPIX.K/WCPIXN.K

 2026  NTINH.K=(MNHEMR.K)(MR.K/100)-(TAH.K)(ADR.K/100)-(RH.K)(RDR.K/100)
```

The model distinguishes between two types of families: families under Active Heads or Active Families and families under Retired Heads or Retired Families. A family of the former type consists of both economically active and non-active members under 65 while a family of the latter type consists only of non-active members over 65. For the purposes of the model heads of families are used as the basis for the generation of population changes. Every head is implicitly considered as married i.e. no single-member families are identified. Inflows and outflows of heads result in proportional popula-

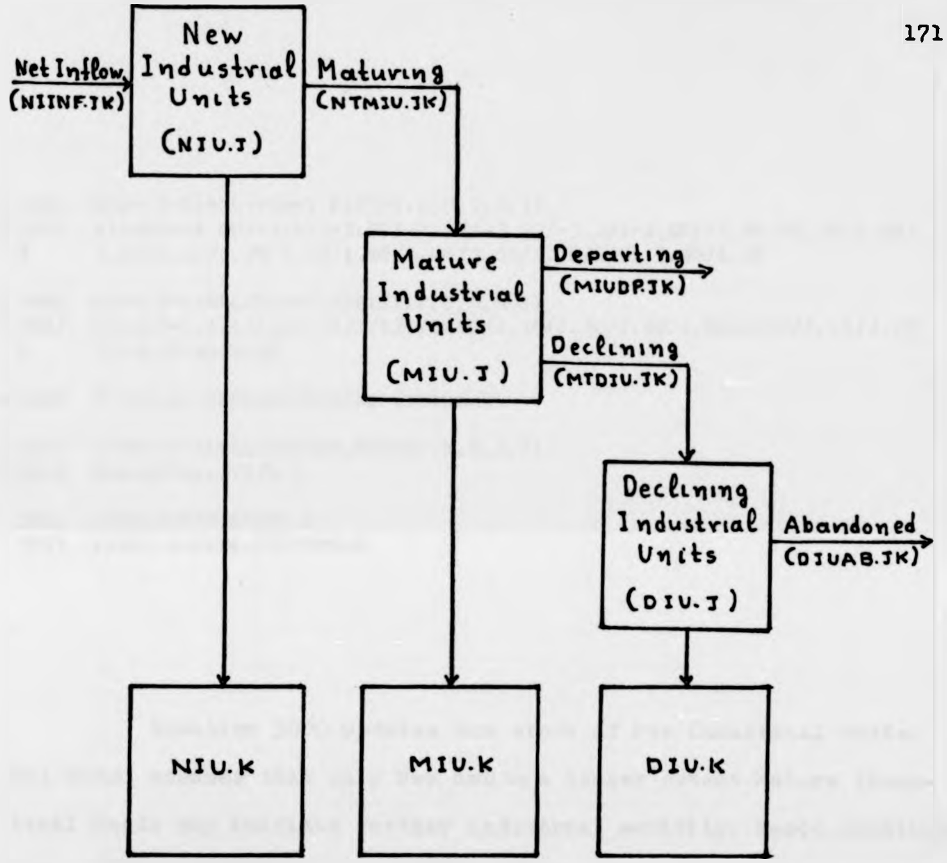

Figure 8.9

Industrial Units Sector

8.3.1 New Industrial Units

The following set of equations simulates the flows of New Industrial Units into and out in the given city.

```
*3000  NIU.K=NIU.J+(NIINF.JK-NTMIU.JK)(DT)

*3001  NIINEX.K=MIN((NIU.K)(NIAF)((NIINRN.K/100)+(ANIINR.K)(NIAM.K-1))+(M
 X     IU.K)(MIAF)((NIINRN.K/100)+(ANIINR.K)(MIAM.K-1)),EXIBAV.K)
*3002  NIINF.KL=(NIINEX.K)(AXMULT)+NICRPG.K
*3003  ANIINR.K=(AHINRN.K/100)(TAH.K)(0.935)((1+NHEAPF.K)/10)/((NIU.K)(NI
 X     AF)+(MIU.K)(MIAF))
```

tion changes and so do their natural increase (through marriage) and death. On the basis of this assumption equations 2000 and 2001 generate the number of non-heads in families under Retired and Active Heads respectively.

Equation 2002 generates the total number of active non-heads by using the exogenously provided number of active non-heads per family. For reasons of simplicity,the distribution of active non-heads into the three occupational groups is considered as identical to that of family heads (eqs 2003-2005); in other words,the processes of training and deskilling are taken into account only indirectly in the case of non-heads.

The next four equations concern the generation of new heads through marriage. Equation 2006 computes the number of male non-heads whoare eligible for marriage by using the exogenously provided proportion of males in the population; equation 2009 computes the actual number of marriages by using the also exogenously provided Marriage Rate.

Finally,the remaining equations generate various population statistics which will be used in subsequent sectors.

8.3 INDUSTRIAL UNITS SECTOR

The last two sectors were devoted to the generation of population movement. The present sector covers the generation of industrial activity. For the purposes of the model,industrial activity is expressed in terms of industrial units which are divided into three groups: New, Mature and Declining. For reasons of simplification this sector has also been divided into three sections each covering one of the industrial unit groups. Figure 8.9 illustrates graphically the process described in this sector.

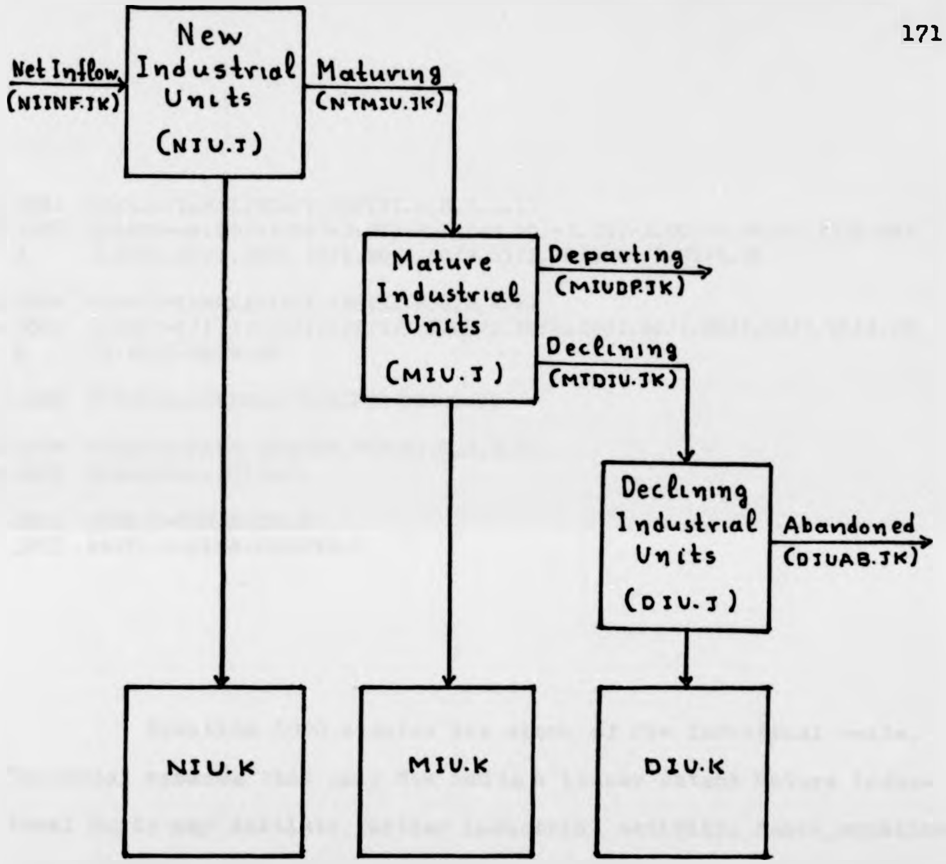

Figure 8.9

Industrial Units Sector

8.3.1 New Industrial Units

The following set of equations simulates the flows of New Industrial Units into and out in the given city.

```
*3000  NIU.K=NIU.J+(NIINF.JK-NTMIU.JK)(DT)

*3001  NIINEX.K=MIN((NIU.K)(NIAF)((NIINRN.K/100)+(ANIINR.K)(NIAM.K-1))+(M
 X     IU.K)(MIAF)((NIINRN.K/100)+(ANIINR.K)(MIAM.K-1)),EXIBAV.K)
*3002  NIINF.KL=(NIINEX.K)(AXMULT)+NICRPG.K
*3003  ANIINR.K=(AHINRN.K/100)(TAH.K)(0.935)((1+NHEAPF.K)/10)/((NIU.K)(NI
 X     AF)+(MIU.K)(MIAF))
```

```
* 3004  NIAM.K=TABHL(NIAMT,PSPINI.K,0,2,0.1)
* 3005  NIAMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-3.20/-2.00/-1.50/-0.30/0.80/
  X     1.00/1.10/1.20/1.40/1.80/3.00/3.55/3.70/3.85/3.90/4.00

* 3006  MIAM.K=TABHL(MIAMT,PSPINI.K,0,2,0.1)
* 3007  MIAMT*=1/1/1/1/1/1/1/1/1/1/1.00/1.10/1.20/1.40/1.80/3.00/3.55/3.70
  X     /3.85/3.90/4.00

* 3008  NTMIU.KL=(NIU.K)(NIDCRN)(NIDCM.K)

* 3009  NIDCM.K=TABHL(NIDCMT,PSPINI.K,0,2,1)
* 3010  NIDCMT*=1.3/1/0.5

  3011  NIFR.K=NIU.K/TIU.K
  3012  RNIFR.K=NIFR.K/NIFRN.K
```

Equation 3000 updates the stock of New Industrial Units. The model assumes that only New and to a lesser extent Mature Industrial Units may initiate further industrial activity; hence, equations 3001, 3002 generate the net inflow of New Industries over a given period as a function of a weighted combination of the New and Mature Units existing at the beginning of the period. This net inflow covers industries attracted from outside the city as well as expanding industries. The normal net inflow rate of industrial units is given exogenously. Furthermore, the model assumes that in the case of a city more or less attractive than the normal city the extra gain or loss of industrial activity is proportional not to the normal inflow rate but to a modified rate (eq. 3003); this takes into account only industrial activity required to satisfy employees arriving from outside the city. Increase in the number of industrial units, however, is also subject to the availability of Fit Industrial Buildings; for the purposes of the model the number of available industrial buildings serves as the upper limit in the expected generation of industrial activity.

Equations 3004-3007 calculate the net inflow multipliers for New Industries. NIAM refers to industrial units attracted by the existing New Industries while MIAM refers to those attracted by the existing Mature Industries. Both multipliers are considered as functions of the corresponding Specific Image of the city. The exact relationships are illustrated in Figures 8.10 and 8.11 respectively.

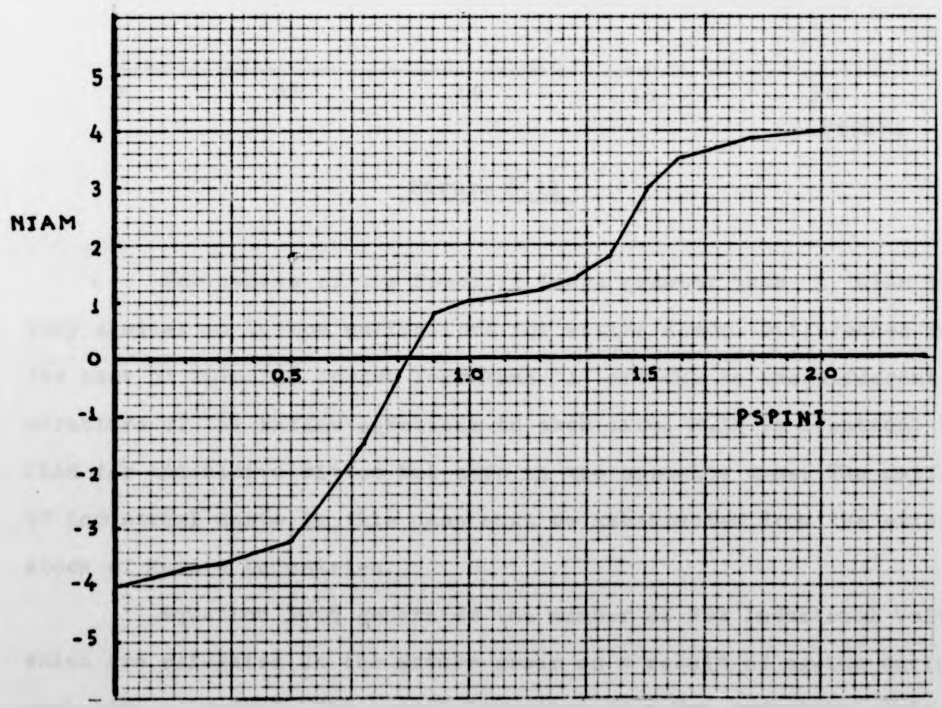

Figure 8.10

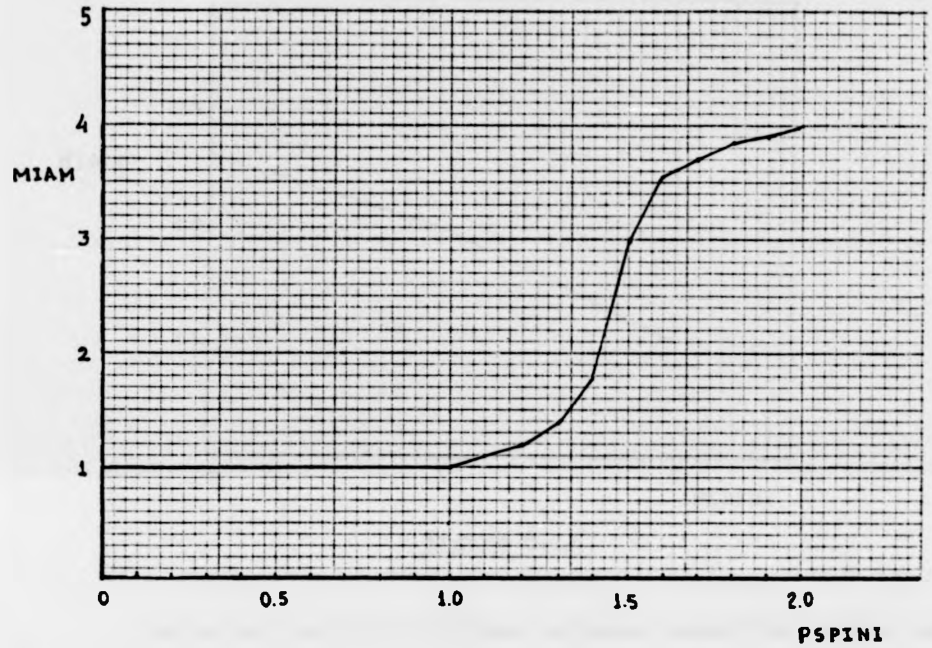

Figure 8.11

For values of the Specific Image greater than 1 NIAM is very similar to inflow multipliers for Active Heads. Differences for the case of Specific Images less than 1 are due to the different structure of the inflow equations in each case. MIAM is identical to NIAM for attractive cities but zero in the opposite case. The outflow of industrial units in this case must be substracted from the existing stock of Mature Industries.

Equation 3008 generates the number of New Industrial Units which are relegated to the mature group as a result of ageing during each time of period. The normal life-time of a New Industrial Unit is taken as 20 years; the model,however, assumes that this may be extended or shortened depending on the demand for industrial units. Equations 3009, 3010 and Figure 8.12 illustrate the effect of industrial conditions, as expressed by the corresponding Specific Image, on the life-time of a New Industrial Unit.

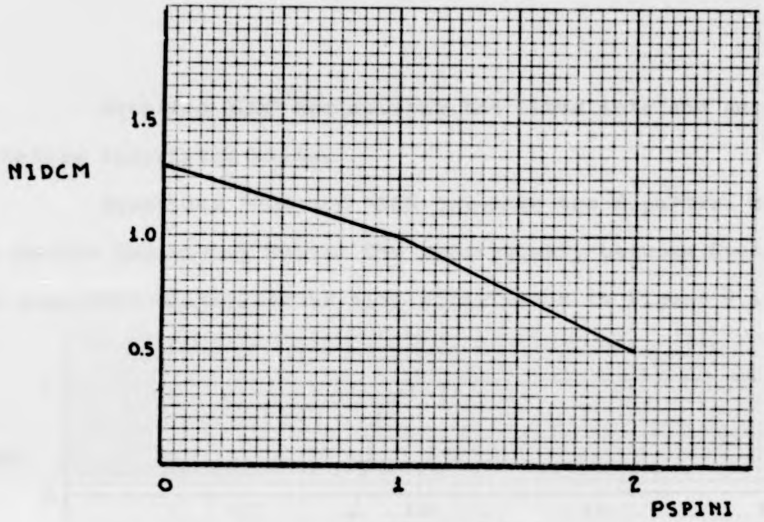

Figure 8.12

As we can see its life-time increases under favourable conditions and decreases in the opposite case.

8.3.2 Mature Industrial Units

The following set of equations generates the movement of Mature Industrial Units.

```
* 3200   MIU.K=MIU.J+(NTMIU.JK-MIUDP.JK-MTDIU.JK)(DT)

* 3201   MIUDP.KL=(MIU.K)(MIAF)(ANIINR.K)(1-MIDPM.K)

* 3202   MIDPM.K=TABHL(MIDPMT,PSPINI.K,0,2,0.1)
* 3203   MIDPMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-3.20/-2.00/-1.50/-0.30/0.80
  X      /1.00/1/1/1/1/1/1/1/1/1/1

* 3204   MTDIU.KL=(MIU.K)(MIDCRN)(MIDCM.K)

* 3205   MIDCM.K=TABHL(MIDCMT,PSPINI.K,0,2,1)
* 3206   MIDCMT*=1.3/1/0.5

  3207   MIFR.K=MIU.K/TIU.K
  3208   RMIFR.K=MIFR.K/MIFRN.K
```

Equation 3200 accumulates the flows into and out of the pool of Mature Industrial Units.

Equations 3202 and 3203 generate the departure multiplier for Mature Industrial Units. The relationship between Specific Image and departure multiplier is also illustrated in Figure 8.13.

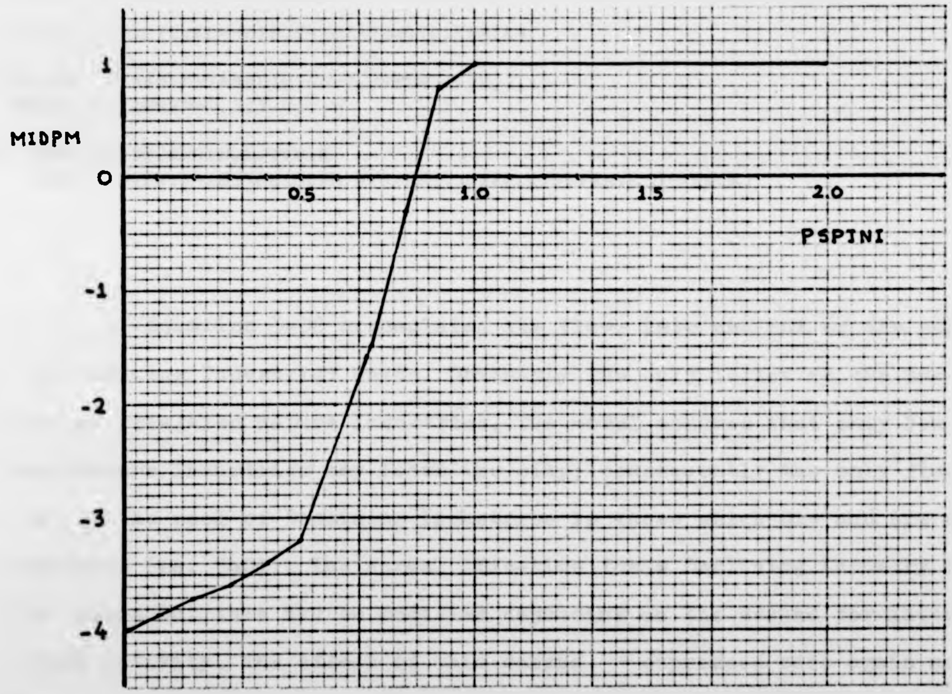

Figure 8.13

The model implicitly assumes that no Mature Industrial Units depart from an attractive city. On the basis of this assumption MIDPM is identical to NIAM for attractive cities but zero in the opposite case.

Equation 3204 generates the number of Mature Industrial Units which are relegated to the declining group. The normal life-time of a Mature Industrial Unit is 30 years and the effect of the existing industrial conditions on it is identical to that described for New Industries (eqs. 3205,3206).

8.3.3 Declining Industrial Units

The movement of Declining Industrial Units is generated by the following set of equations:

```
*3400  DIU.K=DIU.J+(MTDIU.JK-DTABIU.JK)(DT)

*3401  DTABIU.KL=(DIU.K)(DIABRN)(DIABM.K)

*3402  DIABM.K=TABHL(DIABMT,PSPINI.K,0,2,1)
*3403  DIABMT*=0.2/1.0/1.0

 3404  DIFR.K=DIU.K/TIU.K
 3405  RDIFR.K=SWITCH(DIFR.K/0.0001,DIFR.K/DIFRN.K,DIFRN.K)
```

Equation 3400 accumulates the flows into and out of the pool of Declining Industrial Units. Obviously the only inflow is the number of relegated Mature Industries. The model assumes that only New and Mature Industries may leave the city; consequently the only flow out of the pool of Declining Industries is those which die and are abandoned (eq. 3401). The normal life-time for a Declining Industry is 30 years but this may be modified depending on the demand for industrial activity. The effect of this demand — expressed once again as the corresponding Specific Image of the city — on the abandonment rate of Declining Units is illustrated in Figure 8.14.

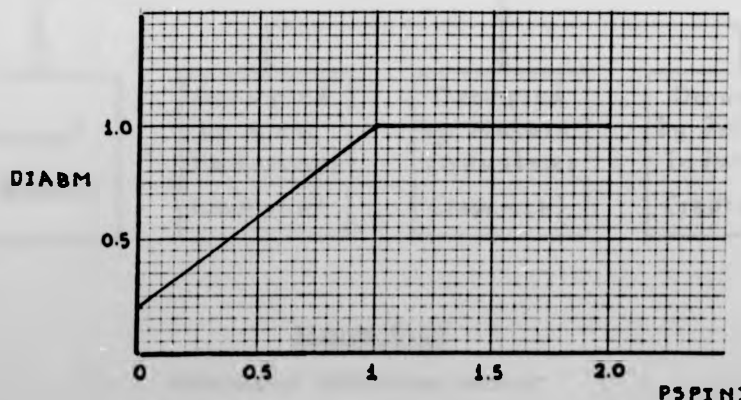

Figure 8.14

8.4 INDUSTRIAL BUILDINGS SECTOR

Industrial units are the generators of industrial activity but industrial buildings provide the necessary infrastructure. The objective of this sector is to update the stock of industrial buildings and to provide information concerning their occupation. Figure 8.15 illustrates graphically the process described in this sector.

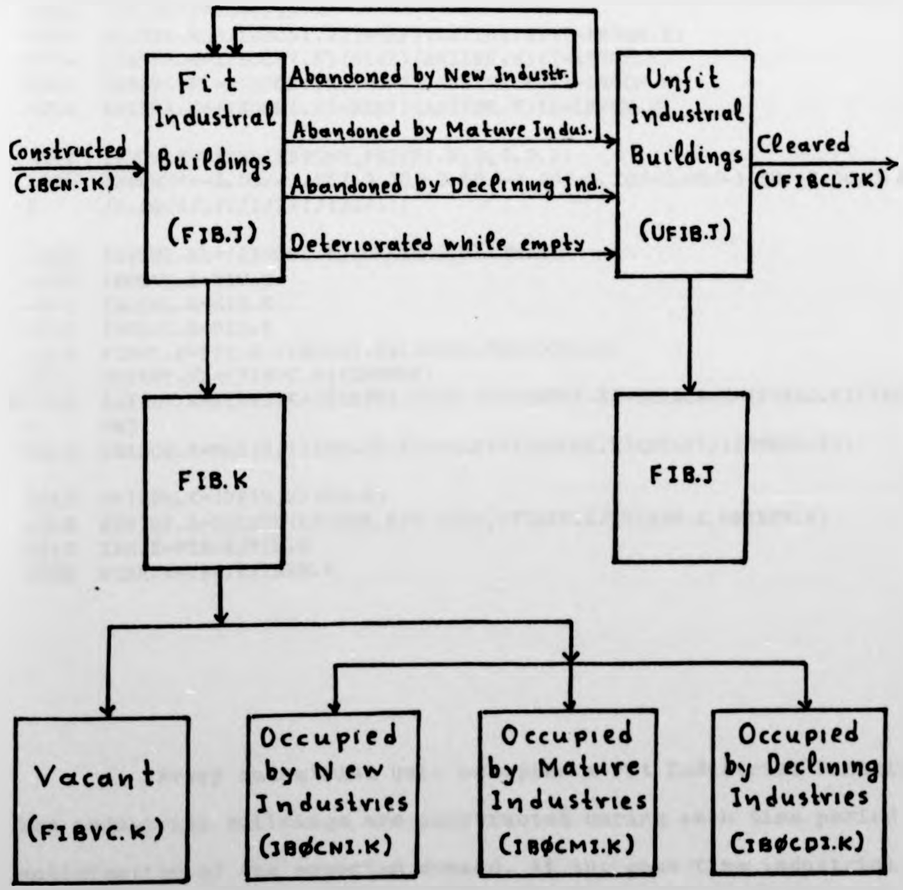

Figure 8.15

Industrial Buildings Sector

The following set of equations simulate the process shown in Figure 8.15.

```
* 4000  FIB.K=FIB.J+(IBCN.JK-(IBVCMI.JK)(0.5)-IBVCDI.JK-VCIBDT.JK)(DT)
* 4001  UFIB.K=UFIB.J+((IBVCMI.JK)(0.5)+IBVCDI.JK+VCIBDT.JK-UFIBCL.JK)(DT)

  4002  TIB.K=FIB.K+UFIB.K
  4003  IBVCNI.KL=(IBOCNI.K)(NIAF)(ANIINR.K)(1-IBVCM.K)
  4004  EIBVNI.K=(IBOCNI.K)(NIAF)(ANIINR.K)(1-IBVCM.K)
  4005  IBVCMI.KL=(IBOCMI.K)(MIAF)(ANIINR.K)(1-IBVCM.K)
  4006  EIBVMI.K=(IBOCMI.K)(MIAF)(ANIINR.K)(1-IBVCM.K)

  4007  IBVCM.K=TABHL(IBVCMT,PSPINI.K,0,2,0.1)
  4008  IBVCMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-3.20/-2.00/-1.50/-0.30/0.80
  X     /1.00/1/1/1/1/1/1/1/1/1/1

  4009  IBVCDI.KL=(IBOCDI.K)(DIABRN)(DIABM.K)
  4010  IBOCNI.K=NIU.K
  4011  IBOCMI.K=MIU.K
  4012  IBOCDI.K=DIU.K
  4013  FIBVC.K=FIB.K-(IBOCNI.K+IBOCMI.K+IBOCDI.K)
  4014  VCIBDT.KL=(FIBVC.K)(IBDTRN)
* 4015  EXIBAV.K=FIBVC.K+(EIBVNI.K+(0.5)(EIBVMI.K)+EXIBCN.K-(FIBVC.K)(IBDT
  X     RN))
  4016  EXIBCN.K=MAX(0,((IBOCNI.K)(NIAF)+(IBOCMI.K)(MIAF))(ICNRFS.K))

  4017  UFIBFR.K=(UFIB.K/TIB.K)
  4018  RUFIBF.K=SWITCH(UFIBFR.K/0.0001,UFIBFR.K/UFIBFN.K,UFIBFN.K)
  4019  IBR.K=FIB.K/TIU.K
  4020  RIBR.K=IBR.K/IBRN.K
```

Every industrial unit occupies a Fit Industrial Building. New industrial buildings are constructed during each time period in anticipation of the expected demand. At the same time industrial buildings deteriorate and become unfit for occupation. The life-time of a vacant industrial building is given exogenously. Regarding the life-time of a Fit Industrial Building the model assumes that all industrial buildings remain fit at least for as long as they are occupied. Furthermore all industrial buildings vacated by New Industrial Units and 50% of the industrial buildings vacated by Mature Industrial Units are fit for reoccupation; whereas industrial buildings vacated by Declining Industrial Units are unfit. On the basis of those assumptions equations 4000 and 4001 update the number of Fit and Unfit Industrial Buildings respectively, whereas equations 4003-4016 generate the various flows involved in the first two equations.

Unlike the case of housing allocation,where a shortage of housing units increases the degree of overcrowding,the existence of a vacant Fit Industrial Building is a necessary condition for the creation of a New Industrial Unit. Under normal conditions the construction of industrial buildings follows closely the creation of New Industrial Units; in certain cases, however, the inability of the city to satisfy the demand for industrial buildings may prove a limit to a fast industrial expansion.

Equation 4015 generates the number of industrial buildings which are expected to be available during the coming period; this number is used as the upper limit for the number of New Industrial Units to be created during that period.

Finally, the remaining equations generate relevant statistics which are used elsewhere in the model

8.5 EMPLOYMENT SECTOR

The model distinguishes between three types of economically active persons classified according to their occupational group and three types of jobs classified according to the skills required for them. The number of potential employees in each occupational

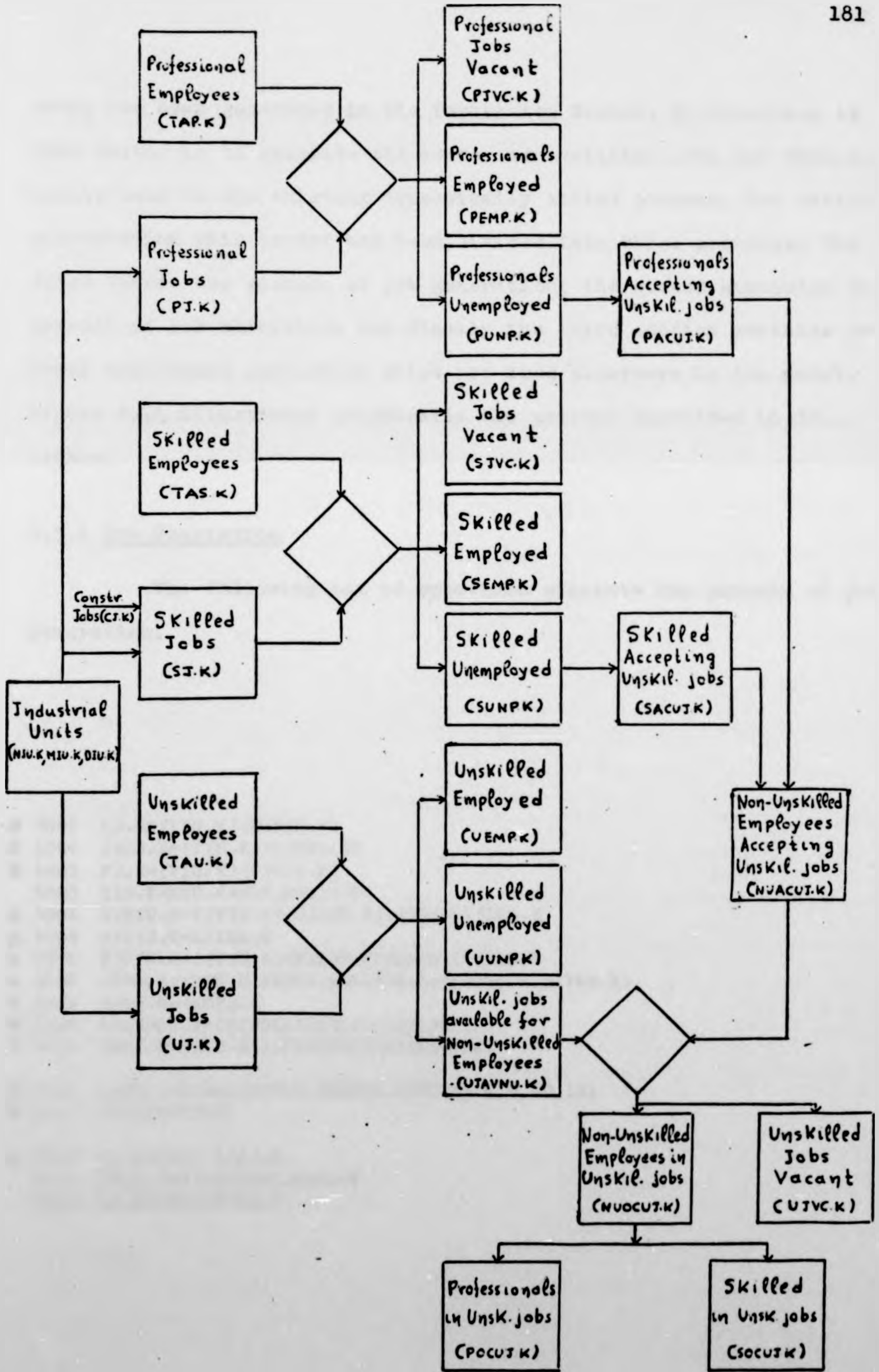

Figure 8.16 Employment Sector

group has been generated in the Population Sector. My objective in this sector is to generate the number of available jobs and then allocate them to the existing economically active persons. For easier presentation this sector has been divided into three sections. The first covers the process of job generation; the second simulates the process of job allocation and finally the third section contains several employment statistics which are used elsewhere in the model. Figure 8.16 illustrates graphically the process described in this sector.

8.5.1 Job Generation

The following set of equations simulate the process of job generation.

```
* 5000  UJ.K=(TIU.K)(UJPIU.K)
* 5001  SNCJ.K=(TIU.K)(SJPIU.K)
* 5002  PJ.K=(TIU.K)(PJPIU.K)
  5003  TIU.K=NIU.K+MIU.K+DIU.K
* 5004  UJPIU.K=((TIU.K)(UJIUN.K)+ADUJ.K)/TIU.K
* 5005  SJPIU.K=SJIUN.K
* 5006  PJPIU.K=((TIU.K)(PJIUN.K)+ADPJ.K)/TIU.K
* 5007  ADPJ.K=(TIU.K)(NIFR.K-NIFRN.K)(PJINN.K/NIFRN.K)
* 5008  ADUJ.K=-ADPJ.K
* 5009  CJ.K=CJ.J+(DT/DEL)(EXCJ.J-CJ.J)
* 5010  EXCJ.K=(TIU.K)(JPIUN)(CJPN)(CJPM.K)

* 5011  CJPM.K=TABHL(CJPMT,TCNRFS.K/TCNRN.K,0,10,10)
* 5012  CJPMT*=0/10

* 5013  SJ.K=SNCJ.K+CJ.K
  5014  TNCJ.K=UJ.K+SNCJ.K+PJ.K
  5015  TJ.K=TNCJ.K+CJ.K
```

Jobs, apart from being classified into three groups according to the required skill, they are also divided into industrial (i.e. provided by industrial units) and construction jobs.

Equations 5000-5002 generate the number of industrial jobs available for each occupational group as a function of the level and the composition of the city's industrial stock.

For the purposes of the model all three types of industrial units are considered as having identical composition. The normal composition of an industrial unit is given exogenously but it may be modified depending on the quality of the existing industrial stock (eqs. 5004-5008). The model assumes that any increase in the number of Professional Jobs per industrial unit is mainly the result of a much higher increase in the number of Professional Jobs per New Industrial Unit. Hence, a high proportion of New Industries among a city's industrial stock results to an increase in the total number of Professional Jobs and a decrease in the total number of Unskilled Jobs.

Equations 5009-5010 generate the number of available Construction Jobs. The normal proportion of Construction Jobs among the total number of jobs is given exogenously but it may be modified depending on the demand for construction; the latter is expressed as the fraction of the feasible construction rate over the normal one. A simple proportional modification is assumed which is illustrated by equations 5011-5012 and Figure 8.17.

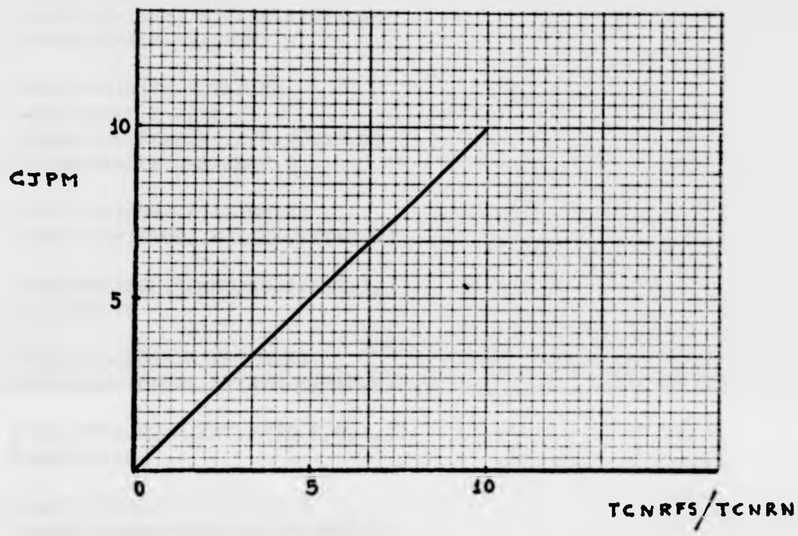

Figure 8.17

The model assumes that all Construction Jobs are Skilled and hence they are added to the corresponding industrial jobs to give the total number of Skilled Jobs available (eq. 5013).

8.5.2 Job Allocation

The following equations simulate the process of job allocation.

```
*5200  UEMP.K=MIN(UJ.K,TAU.K)
 5201  UUNP.K=TAU.K-UEMP.K

 5202  AUHEMP.K=(UEMP.K)(AUH.K/TAU.K)
 5203  AUHUNP.K=AUH.K-AUHEMP.K
*5204  UJAVNU.K=MAX(0,UJ.K-TAU.K)
```

```
*5205  SEMP.K=MIN(SJ.K,TAS.K)
 5206  SUNP.K=TAS.K-SEMP.K
 5207  ASHEMP.K=(SEMP.K)(ASH.K/TAS.K)
 5208  ASHUNP.K=ASH.K-ASHEMP.K

*5209  PEMP.K=MIN(PJ.K,TAP.K)
 5210  PUNP.K=TAP.K-PEMP.K
 5211  APHEMP.K=(PEMP.K)(APH.K/TAP.K)
 5212  APHUNP.K=APH.K-APHEMP.K

*5213  SACUJ.K=(SUNP.K)(SJMM.K)
 5214  SHACUJ.K=(SACUJ.K)(ASH.K/TAS.K)

*5215  SJMM.K=TABHL(SJMMT,RSJR.K,0,1,1)
*5216  SJMMT*=1/0

*5217  PACUJ.K=(PUNP.K)(PJMM.K)
 5218  PHACUJ.K=(PACUJ.K)(APH.K/TAP.K)

*5219  PJMM.K=TABHL(PJMMT,RPJR.K,0,1,1)
*5220  PJMMT*=1/0

 5221  NUACUJ.K=SACUJ.K+PACUJ.K
 5222  NUOCUJ.K=MIN(NUACUJ.K,UJAVNU.K)
*5223  POCUJ.K=(NUOCUJ.K)(PDUJ.K)
 5224  PDUJ.K=SWITCH(0,PACUJ.K/NUACUJ.K,NUACUJ.K)
 5225  APHOUJ.K=(POCUJ.K)(PEMP.K/TAP.K)
*5226  SOCUJ.K=(NUOCUJ.K)(SDUJ.K)
 5227  SDUJ.K=SWITCH(0,SACUJ.K/NUACUJ.K,NUACUJ.K)
 5228  ASHOUJ.K=(SOCUJ.K)(SEMP.K/TAS.K)
 5229  AHOUJ.K=AUHEMP.K+ASHOUJ.K+APHOUJ.K

 5230  UJVC.K=MIN(0,UJ.K-TAU.K-SOCUJ.K-POCUJ.K)
 5231  SJVC.K=MIN(0,SJ.K-TAS.K)
 5233  PJVC.K=MIN(0,PJ.K-TAP.K)

 5234  TUNP.K=UUNP.K+SUNP.K-SOCUJ.K+PUNP.K-POCUJ.K
 5235  TEMP.K=TA.K-TUNP.K
 5236  TAHUNP.K=(TUNP.K)(TAH.K/TA.K)
```

Under normal conditions members of each group are employed only in jobs they are qualified for; in certain cases however, which will be discussed below, members of the two higher groups may also accept unskilled jobs.

Equation 5200 allocates unskilled employees into the available Unskilled Jobs. Similarly equations 5205 and 5209 allocate skilled and professional employees to the corresponding available jobs.

In the case of persistent and higher than normal unemployment some of the unemployed skilled and professionals are prepared to accept any available unskilled jobs (eqs. 5213, 5217). The effect of the job-market state – expressed as the ratio of Skilled Jobs over the prospective employees – on the number of unemployed skilled accepting Unskilled Jobs is described in equations 5215,5216 and illustrated by figure 8.18

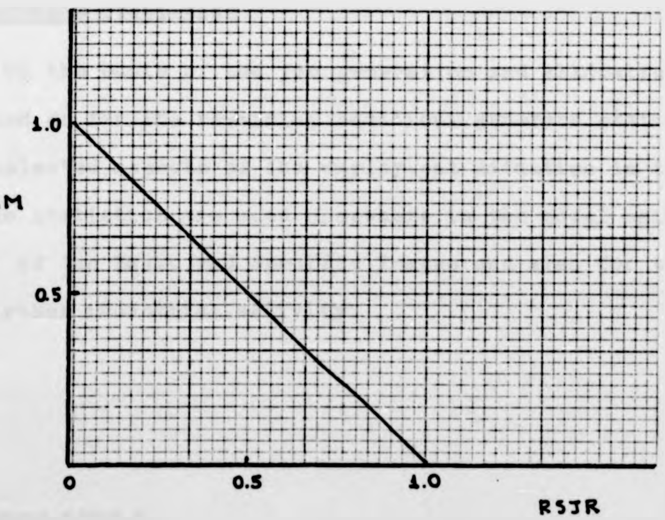

Figure 8.18

The model assumes that in the case of lower than normal unemployment rate no skilled employees occupy Unskilled Jobs. In the opposite case, however, a fraction of the unemployed skilled are prepared to accept Unskilled Jobs; this fraction increases in proportion to the corresponding unemployment rate . The same assumptions are involved in the generation of the unemployed professionals who are prepared to accept Unskilled Jobs (eqs 5217-5220).

Obviously the number of qualified employees who actually get Unskilled Jobs depends also on the number of available jobs (eq. 5204), for which however unskilled workers have priority. In the case of more canditates than jobs the existing jobs are distributed among Skilled and Professionals in proportion to the actual demand (eqs. 5226 5223).

8.5.3 Employment Statistics

On the basis of the job generation and allocation processes outlined so far the remaining equations generate statistics expressing selected aspects of the employment situation in the given city. Those statistics are used elsewhere in the model mainly for the derivation of the Basic and Specific Images and also for the generation of further industrial activity.

```
5400  PJR.K=PJ.K/TAP.K
5401  RPJR.K=PJR.K/PJRN.K
5402  SJR.K=SJ.K/TAS.K
5403  RSJR.K=SJR.K/SJRN.K
5404  UJR.K=UJ.K/(TAU.K+SOCUJ.K+POCUJ.K)
5405  RUJR.K=UJR.K/UJRN.K
5406  TJR.K=TJ.K/TA.K
5407  RTJR.K=TJR.K/TJRN.K
5408  UNPRT.K=(TUNP.K)(100/TA.K)
5409  RUNPR.K=SWITCH(UNPRT.K/0.00001,UNPRT.K/UNPRTN.K,UNPRTN.K)
5410  ICPIX.K=((NIU.K)(2)+(MIU.K)(1))/TIU.K

5411  RICPIX.K=ICPIX.K/ICPIXN.K
```

8.6 SKILL-INCOME CONVERSION SECTOR

Heads of families have so far been classified according to their skill, and their attraction to the city has been expressed in terms of the corresponding net inflow multipliers. My objectives in this sector are firstly, to reclassify the existing heads of families according to their income level and secondly, to derive the net inflow multipliers for the various groups of potential movers classified according to their income. Figure 8.19 illustrates graphically the process of reclassification.

The following set of equations simulate the process shown in Figure 8.19.

```
* 6000  HIH.K=APHEMP.K+(APHUNP.K-PHACUJ.K)
* 6001  MIH.K=ASHEMP.K+(ASHUNP.K-SHACUJ.K)
* 6002  LIH.K=AHOUJ.K+(PHACUJ.K-APHOUJ.K)+(SHACUJ.K-ASHOUJ.K)+AUHUNP.K+RH.
  X     K
  6003  ALIH.K=LIH.K-RH.K

* 6004  PSPIHI.K=PSPIAP.K
* 6005  PSPIMI.K=PSPIAS.K
* 6006  PSPILI.K=PSPIAU.K

* 6007  HIHINM.K=PHINM.K
* 6008  MIHINM.K=SHINM.K
* 6009  LIHINM.K=UHINM.K

  6010  NTINLI.K=(NTINH.K)(ALIH.K/TAH.K)
  6011  NINLIM.K=(ALIH.K)(AHINRN.K/100)
  6012  EINLIM.K=(NINLIM.K)(LIHINM.K)

  6013  NTINMI.K=(NTINH.K)(MIH.K/TAH.K)
  6014  NINMIM.K=(MIH.K)(AHINRN.K/100)
  6015  EINMIM.K=(NINMIM.K)(MIHINM.K)

  6016  NTINHI.K=(NTINH.K)(HIH.K/TAH.K)
  6017  NINHIM.K=(HIH.K)(AHINRN.K/100)
  6018  EINHIM.K=(NINHIM.K)(HIHINM.K)

  6019  HIHFR.K=HIH.K/TH.K
  6020  MIHFR.K=MIH.K/TH.K
  6021  LIHFR.K=LIH.K/TH.K

  6022  MHIHFR.K=HIH.K/(HIH.K+MIH.K+(LIH.K/1.35))
  6023  MMIHFR.K=MIH.K/(HIH.K+MIH.K+(LIH.K/1.35))
  6024  MLIHFR.K=(LIH.K/1.35)/(HIH.K+MIH.K+(LIH.K/1.35))
```

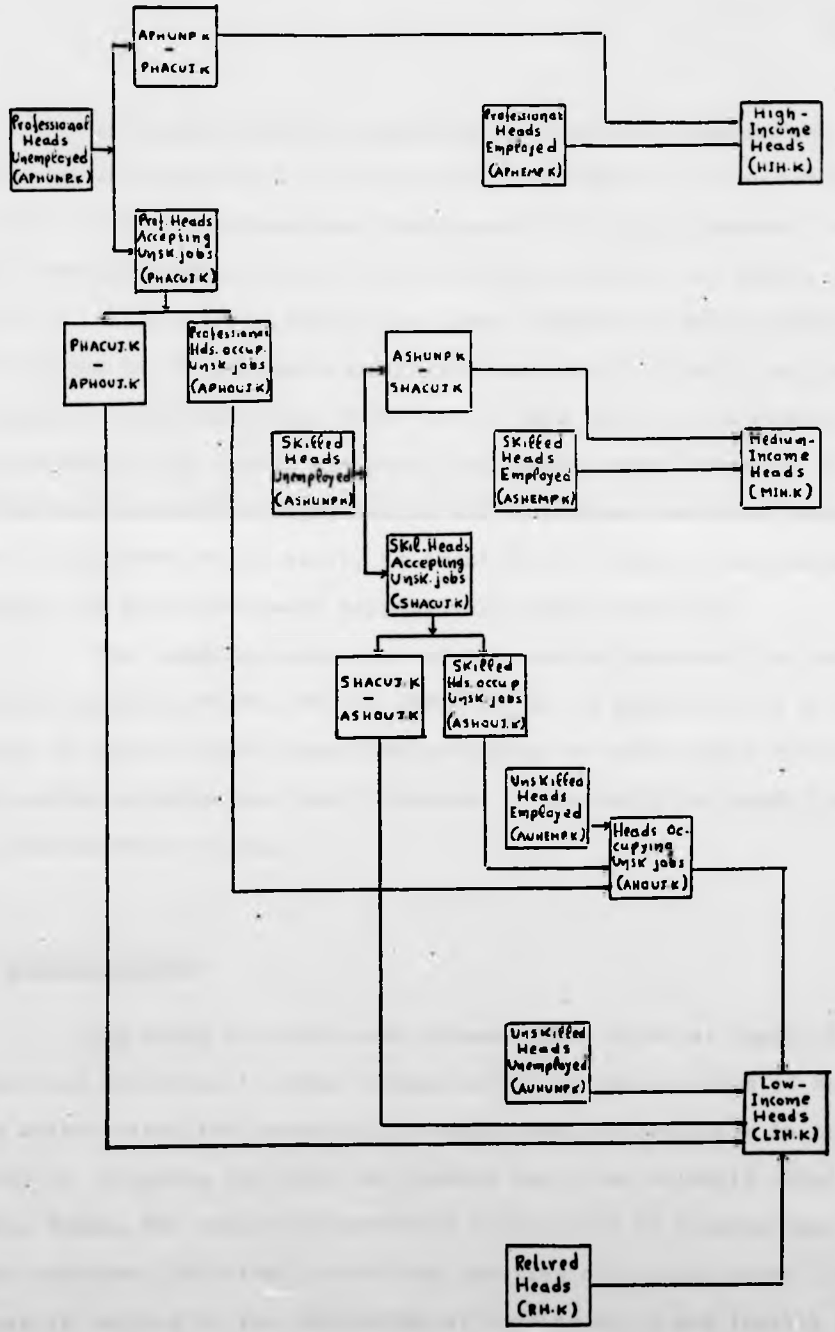

Figure 8.19

Skill-Income Conversion Sector

Although a detailed skill-income conversion method may be used, for the purposes of the model and for reasons of simplifications I assume that all Professional Heads,apart from those prepared to accept Unskilled Jobs,belong to the high-income group (eq. 6000). Similarly all Skilled Heads,except for those prepared to accept Unskilled Jobs,belong to the medium-income group (eq. 6001). Finally, all heads occupied in Unskilled Jobs, those out of work and all the retired ones belong to the low-income group (eq. 6002). Thus, Specific Images & inflow multipliers for High, Medium and Low-Income Heads are taken, for the purposes of the model, as identical to those of Professional, Skilled and Unskilled Heads respectively (eqs. 6004-6009).

The remaining equations of this sector generate the normal natural increase as well as the increase due to migration for all groups of Active Heads classified according to their income level. The results obtained are used elsewhere in the model and mainly in the construction sector.

8.7 HOUSING SECTOR

The model distinguishes between three types of family heads classified according to their income level and three groups of housing units classified according to their cost. My objective in this sector is to update the stock of housing units and allocate them to family heads. For easier presentation this sector is divided into three sections. The first covers the updating of housing stock , the second is devoted to the allocation of housing units and finally the third contains housing statistics used elsewhere in the model. Figure 8.20 illustrates graphically the processes described in this sector.

Although a detailed skill-income conversion method may be used, for the purposes of the model and for reasons of simplifications I assume that all Professional Heads, apart from those prepared to accept Unskilled Jobs, belong to the high-income group (eq. 6000). Similarly all Skilled Heads, except for those prepared to accept Unskilled Jobs, belong to the medium-income group (eq. 6001). Finally, all heads occupied in Unskilled Jobs, those out of work and all the retired ones belong to the low-income group (eq. 6002). Thus, Specific Images & inflow multipliers for High, Medium and Low-Income Heads are taken, for the purposes of the model, as identical to those of Professional, Skilled and Unskilled Heads respectively (eqs. 6004-6009).

The remaining equations of this sector generate the normal natural increase as well as the increase due to migration for all groups of Active Heads classified according to their income level. The results obtained are used elsewhere in the model and mainly in the construction sector.

8.7 HOUSING SECTOR

The model distinguishes between three types of family heads classified according to their income level and three groups of housing units classified according to their cost. My objective in this sector is to update the stock of housing units and allocate them to family heads. For easier presentation this sector is divided into three sections. The first covers the updating of housing stock, the second is devoted to the allocation of housing units and finally the third contains housing statistics used elsewhere in the model. Figure 8.20 illustrates graphically the processes described in this sector.

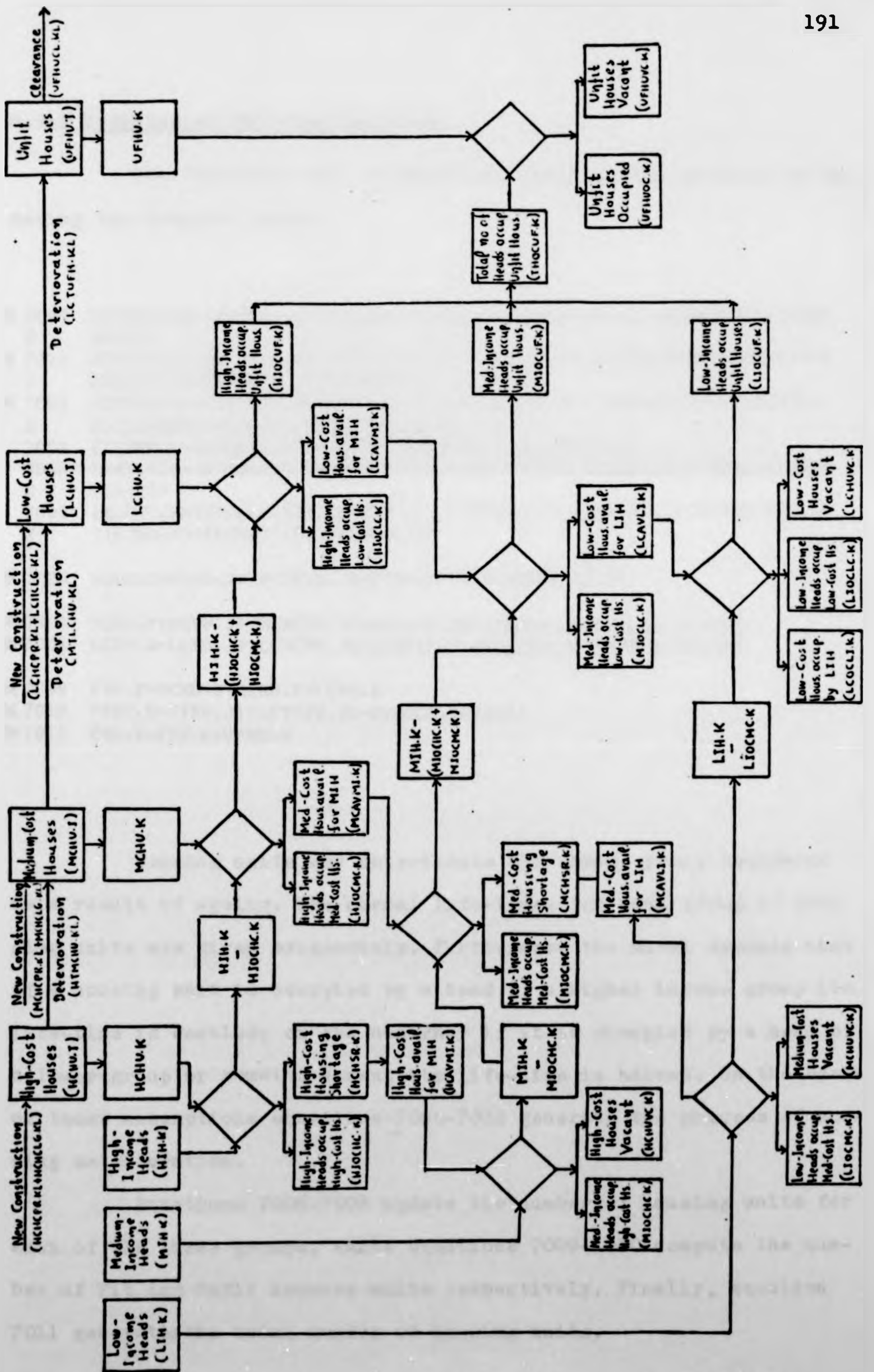

Figure 8.20 Housing Sector

8.7.1 Updating of the Housing Stock

The following set of equations simulate the process of updating the housing stock.

```
* 7000  HTMCHU.KL=(HIOCHC.K)(HCHDRN)+(MIOCHC.K)(HCHDRN)(2)+(HCHUVC.K)(HCHD
  X     RN)(2)
* 7001  MTLCHU.KL=(HIOCMC.K)(MCHDRN)(1/2)+(MIOCMC.K)(MCHDRN)+(LIOCMC.K)(LC
  X     HDRN)(2)+(MCHUVC.K)(MCHDRN)(2)
* 7002  LCTUFH.KL=(HIOCLC.K)(LCHDRN)(1/2)+(MIOCLC.K)(LCHDRN)(1/2)+(LCOCLI.
  X     K)(LCHDRN)+(LCHUVC.K)(LCHDRN)(2)
  7003  EXHTMC.K=(HIOCHC.K)(HCHDRN)+(MIOCHC.K)(HCHDRN)(2)
  7004  EXMTLC.K=(HIOCMC.K)(MCHDRN)(1/2)+(MIOCMC.K)(MCHDRN)+(LIOCMC.K)(LCH
  X     DRN)(2)
  7005  EXLCTU.K=(HIOCLC.K)(LCHDRN)(1/2)+(MIOCLC.K)(LCHDRN)(1/2)+(LCOCLI.K
  X     )(LCHDRN)+(LCHUVC.K)(LCHDRN)(2)

* 7006  HCHU.K=HCHU.J+(HCHCPR.JK+HCHCLG.JK-HTMCHU.JK)(DT)

* 7007  MCHU.K=MCHU.J+(MCHCPR.JK+MCHCLG.JK+HTMCHU.JK-MTLCHU.JK)(DT)
* 7008  LCHU.K=LCHU.J+(LCHCPR.JK+LCHCLG.JK+MTLCHU.JK-LCTUFH.JK)(DT)

* 7009  FHU.K=HCHU.K+MCHU.K+LCHU.K
* 7010  UFHU.K=UFHU.J+(LCTUFH.JK-UFHUCL.JK)(DT)
* 7011  THU.K=FHU.K+UFHU.K
```

Housing units may deteriorate and change group downwards as a result of ageing. The normal life-times for each group of housing units are given exogenously. Furthermore the model assumes that if a housing unit is occupied by a head of a higher income group its life-time is doubled; on the contrary if it is occupied by a head of a lower group or remains vacant its life-time is halved. On the basis of those assumptions equations 7000-7002 generate the process of housing deterioration.

Equations 7006-7008 update the number of housing units for each of the three groups, while equations 7009-7010 compute the number of Fit and Unfit housing units respectively. Finally, equation 7011 generates the total number of housing units.

8.7.1 Updating of the Housing Stock

The following set of equations simulate the process of updating the housing stock.

```
* 7000  HTMCHU.KL=(HIOCHC.K)(HCHDRN)+(MIOCHC.K)(HCHDRN)(2)+(HCHUVC.K)(HCHD
  X     RN)(2)
* 7001  MTLCHU.KL=(HIOCMC.K)(MCHDRN)(1/2)+(MIOCMC.K)(MCHDRN)+(LIOCMC.K)(LC
  X     HDRN)(2)+(MCHUVC.K)(MCHDRN)(2)
* 7002  LCTUFH.KL=(HIOCLC.K)(LCHDRN)(1/2)+(MIOCLC.K)(LCHDRN)(1/2)+(LCOCLI.
  X     K)(LCHDRN)+(LCHUVC.K)(LCHDRN)(2)
  7003  EXHTMC.K=(HIOCHC.K)(HCHDRN)+(MIOCHC.K)(HCHDRN)(2)
  7004  EXMTLC.K=(HIOCMC.K)(MCHDRN)(1/2)+(MIOCMC.K)(MCHDRN)+(LIOCMC.K)(LCH
  X     DRN)(2)
  7005  EXLCTU.K=(HIOCLC.K)(LCHDRN)(1/2)+(MIOCLC.K)(LCHDRN)(1/2)+(LCOCLI.K
  X     )(LCHDRN)+(LCHUVC.K)(LCHDRN)(2)

* 7006  HCHU.K=HCHU.J+(HCHCPR.JK+HCHCLG.JK-HTMCHU.JK)(DT)

* 7007  MCHU.K=MCHU.J+(MCHCPR.JK+MCHCLG.JK+HTMCHU.JK-MTLCHU.JK)(DT)
* 7008  LCHU.K=LCHU.J+(LCHCPR.JK+LCHCLG.JK+MTLCHU.JK-LCTUFH.JK)(DT)

* 7009  FHU.K=HCHU.K+MCHU.K+LCHU.K
* 7010  UFHU.K=UFHU.J+(LCTUFH.JK-UFHUCL.JK)(DT)
* 7011  THU.K=FHU.K+UFHU.K
```

Housing units may deteriorate and change group downwards as a result of ageing. The normal life-times for each group of housing units are given exogenously. Furthermore the model assumes that if a housing unit is occupied by a head of a higher income group its life-time is doubled; on the contrary if it is occupied by a head of a lower group or remains vacant its life-time is halved. On the basis of those assumptions equations 7000-7002 generate the process of housing deterioration.

Equations 7006-7008 update the number of housing units for each of the three groups, while equations 7009-7010 compute the number of Fit and Unfit housing units respectively. Finally, equation 7011 generates the total number of housing units.

8.7.2 Housing Allocation.

The following set of equations simulate the process of housing allocation.

```
 7200 HIOCHC.K=MIN(HIH.K,HCHU.K)
 7201 HCHSR.K=MAX(0,HCHU.K-HIH.K)
*7202 HCAVMI.K=(HCHSR.K)(HCHMM.K)

*7203 HCHMM.K=TABHL(HCHMMT,RHCHR.K,0,1,1)
*7204 HCHMMT*=1/0

 7205 HIOCMC.K=MAX(0,HIH.K-HIOCHC.K)
 7206 HIOCLC.K=MAX(0,HIH.K-HIOCHC.K-HIOCMC.K)
 7207 HIOCUF.K=MAX(0,HIH.K-HIOCHC.K-HIOCMC.K-HIOCLC.K)
 7208 MCAVMI.K=MAX(0,MCHU.K-HIOCMC.K)

 7209 LCAVMI.K=MAX(0,LCHU.K-HIOCLC.K)
 7210 MIOCHC.K=MIN(MIH.K,HCAVMI.K)
 7211 MIOCMC.K=MIN(MCAVMI.K,MIH.K-MIOCHC.K)
 7212 MCHSR.K=MAX(0,MCHU.K-HIOCMC.K-MIOCMC.K)
*7213 MCAVLI.K=(MCHSR.K)(MCHMM.K)

*7214 MCHMM.K=TABHL(MCHMMT,RMCHR.K,0,1,1)
*7215 MCHMMT*=1/0

 7216 MIOCLC.K=MIN(LCAVMI.K,MIH.K-MIOCHC.K-MIOCMC.K)
 7217 MIOCUF.K=MAX(0,MIH.K-MIOCHC.K-MIOCMC.K-MIOCLC.K)
 7218 LCAVLI.K=MAX(0,LCHU.K-HIOCLC.K-MIOCLC.K)

 7219 LIOCHC=0
 7220 LIOCMC.K=MIN(LIH.K,MCAVLI.K)
 7221 LIOCLC.K=MIN((LCAVLI.K)(1.35),LIH.K-LIOCMC.K)
 7222 LCOCLI.K=MIN(LCAVLI.K,LIH.K-LIOCMC.K)
 7223 LIOCUF.K=MAX(0,LIH.K-LIOCMC.K-LIOCLC.K)

 7224 THOCHC.K=HIOCHC.K+MIOCHC.K
 7225 THOCMC.K=HIOCMC.K+MIOCMC.K+LIOCMC.K
 7226 THOCLC.K=HIOCLC.K+MIOCLC.K+LIOCLC.K
 7227 THOCUF.K=HIOCUF.K+MIOCUF.K+LIOCUF.K

 7228 HCHUVC.K=MAX(0,HCHU.K-THOCHC.K)
 7229 MCHUVC.K=MAX(0,MCHU.K-THOCMC.K)
 7230 LCHUVC.K=MAX(0,LCHU.K-THOCLC.K)
 7231 UFHUVC.K=MAX(0,UFHU.K-THOCUF.K)
 7232 UFHUOC.K=MIN(UFHU.K,THOCUF.K)

 7233 FHOCHI.K=HIOCHC.K+HIOCMC.K+HIOCLC.K
 7234 FHOCMI.K=MIOCHC.K+MIOCMC.K+MIOCLC.K
 7235 FHOCLI.K=LIOCHC.K+LIOCMC.K+LCOCLI.K
 7236 FHUOC.K=FHOCHI.K+FHOCMI.K+FHOCLI.K

 7237 HUOCHI.K=FHOCHI.K+HIOCUF.K

 7238 HUOCMI.K=FHOCMI.K+MIOCUF.K
 7239 HUOCLI.K=FHOCLI.K+LIOCUF.K
```

Under normal conditions,heads of any income group may occupy housing units of the corresponding or lower group; in certain cases, however, which will be discussed below, they may also occupy housing units of a higher group.

Equations 7200-7207 generate the allocation of housing units to High-Income Heads. The model assumes that they have priority in housing occupation over any other head, Consequently,they start by occupying the available High-Cost Housing Units and they move on to lower groups until the demand is satisfied. Occupation of Low-Cost and Unfit Housing Units by High-Income Heads is possible but extremely unlikely. In case of persistently low demand and higher than normal vacancy rate some of the vacant High-Cost Houses may be available for Medium-Income Heads (eq. 7202). The effect of the housing-market state — expressed as the high-cost housing vacancy rate — on the number of those houses is described by equations 7203,7204 and illustrated in Figure 8.21.

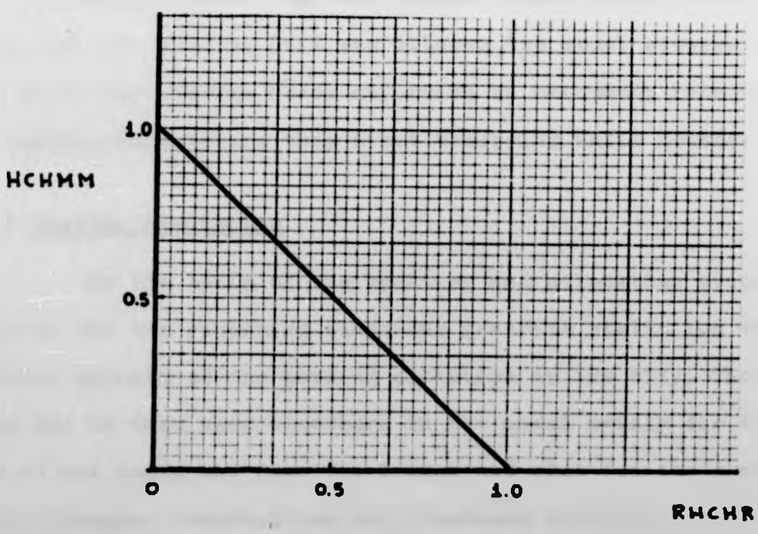

Figure 8.21

The model assumes that in the case of lower than normal vacancy rate no High-Cost Houses are available for Heads of lower income. In the opposite case, however, a fraction of the vacant High-Cost Houses are offered to them; this fraction increases in proportion to the corresponding vacancy rate.

Housing occupation by Medium-Income Heads follows a similar pattern (eqs. 7208-7217). They start by occupying any available High-Cost Housing Units and they go on to houses of lower groups until the demand is satisfied. As in the previous case occupation of Unfit Houses is possible but unlikely. In the case of higher than normal vacancy rate certain Medium-Cost Houses are available for Low-Income Heads (eq. 7213). The actual number depends on the state of the housing market and the assumptions made for the case of High-Cost Houses hold in this case as well (eqs. 7214-7215).

Finally equations 7218-7223 generate the distribution of Low-Income Heads into the remaining Fit and Unfit Houses. Unlike the case of families under High and Medium-Income Heads, where only one family per Fit Housing Unit was allowed,the model assumes that families under Low -Income Heads may reach an occupancy rate of 1.35 per Fit Housing Unit before they start occupying Unfit Houses.

8.7.3 Housing Statistics

On the basis of the updating and allocation processes outlined so far the remaining equations generate statistics expressing selected aspects of the housing situation in the city. Those statistics are in turn used elsewhere in the model mainly for the derivation of the Basic and Specific Images and also for the generation of further housing construction and clearance activity.

```
7400  HCHR.K=HIH.K/HCHU.K
7401  RHCHR.K=HCHR.K/HCHRN.K
7402  MCHR.K=MIH.K/MCHU.K
7403  RMCHR.K=MCHR.K/MCHRN.K
7404  TLCHR.K=LIH.K/LCHU.K
7405  RTLCHR.K=TLCHR.K/TLCHRN.K
7406  LCHR.K=LIH.K/(LCHU.K+LIOCUF.K)
7407  RLCHR.K=LCHR.K/LCHRN.K
7408  HR.K=TH.K/THU.K
7409  RHR.K=HR.K/HRN.K
7410  FHR.K=TH.K/FHU.K
7411  RFHR.K=FHR.K/FHRN.K
7412  HCHFR.K=HCHU.K/THU.K
7413  RHCHFR.K=HCHFR.K/HCHFRN.K
7414  MCHFR.K=MCHU.K/THU.K
7415  RMCHFR.K=MCHFR.K/MCHFRN.K
7416  LCHFR.K=LCHU.K/THU.K
7417  RLCHFR.K=LCHFR.K/LCHFRN.K
7418  UFHFR.K=(UFHU.K/THU.K)
7419  RUFHFR.K=SWITCH(UFHFR.K/0.0001,UFHFR.K/UFHFRN.K,UFHFRN.K)
7420  UFOCR.K=(THOCUF.K/TH.K)
7421  RUFOCR.K=SWITCH(UFOCR.K/0.0001,UFOCR.K/UFOCRN.K,UFOCRN.K)
7422  HQLIX.K=((LCHU.K)(1)+(MCHU.K)(2)+(HCHU.K)(3))/THU.K
7423  RHQLIX.K=HQLIX.K/HQLIXN.K
```

8.8 CONSTRUCTION SECTOR

My objective in this sector is to generate the construction of both industrial buildings and housing units. For easier presentation this sector has been divided into three sections. The first generates the city plans for housing construction; the second covers the plans for industrial construction and finally the third generates the realisation process for both housing and industrial construction plans. Figure 8.22 illustrates graphically the processes described in this sector.

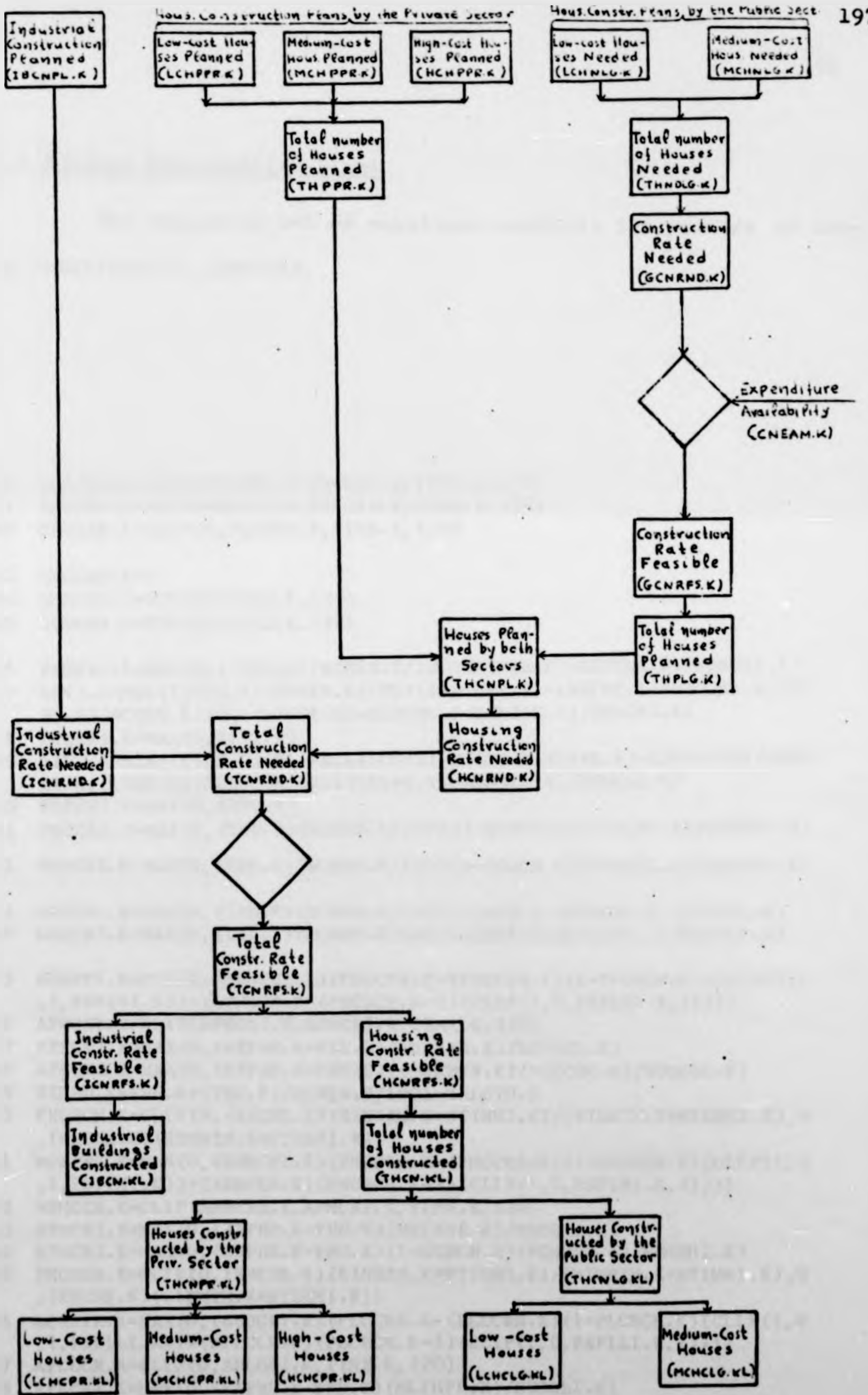

Figure 8.22 Construction Sector

8.8.1 Housing Construction Plans

The following set of equations simulate the process of housing construction planning.

```
 8000  PHCCRN.K=CLIP(PHCCR2.K,PHCCR1.K,TIME.K,120)
 8001  PMCCRN.K=CLIP(PMCCR2.K,PMCCR1.K,TIME.K,120)
 8002  PLCCRN.K=CLIP(0,PLCCR1.K,TIME.K,120)

 8003  GHCCRN.K=0
 8004  GMCCRN.K=STEP(GMCCR2.K,120)
 8005  GLCCRN.K=STEP(GLCCR2.K,120)

 8006  PHCCR1.K=MAX(0,((THU.K)(HCNRN.K/100)(HIHFR.K)+EXHTMC.K)/HUOCHI.K)
 8007  AXV1.K=MIN(((THU.K)(HCNRN.K/100)(1-HIHFR.K)-EXHTMC.K)/HUOCMI.K,((T
 X     HU.K)(HCNRN.K/100)(MIHFR.K)-EXHTMC.K+EXMTLC.K)/HUOCMI.K)
 8008  PMCCR1.K=MAX(0,AXV1.K)
 8009  AXV2.K=MIN(((THU.K)(HCNRN.K/100)(1-HIHFR.K-MIHFR.K)-EXMTLC.K)/HUOC
 X     LI.K,((THU.K)(HCNRN.K/100)(LIHFR.K)-EXMTLC.K)/HUOCLI.K)
 8010  PLCCR1.K=MAX(0,AXV2.K)
 8011  PHCCR2.K=MAX(0,(THU.K)(HCNRN.K/100)(1-GCHCN.K)(PCHCHC.K)/HUOCHI.K)

 8012  PMCCR2.K=MAX(0,(THU.K)(HCNRN.K/100)(1-GCHCN.K)(PCMCHC.K)/HUOCMI.K)

 8013  GMCCR2.K=MAX(0,(THU.K)(HCNRN.K/100)(GCHCN.K)(GCMCHC.K)/HUOCMI.K)
 8014  GLCCR2.K=MAX(0,(THU.K)(HCNRN.K/100)(GCHCN.K)(GCLCHC.K)/HUOCLI.K)

*8015  HCHPPR.K=MAX(0,(HUOCHI.K)(PHCCRN.K-(PHCCRN.K)(1-PHCHCM.K)(CLIP(1,0
 X     ,1,PSPIHI.K))+(APHCCR.K)(PHCHCM.K-1)(CLIP(1,0,PSPIHI.K,1))))
 8016  APHCCR.K=CLIP(APHCR2.K,APHCR1.K,TIME.K,120)
 8017  APHCR1.K=MAX(0,(EXFHU.K-FHU.K)(MHIHFR.K)/HUOCHI.K)
 8018  APHCR2.K=MAX(0,(EXFHU.K-FHU.K)(1-GCHCN.K)(PCHCHC.K)/HUOCHI.K)
 8019  EXFHU.K=FHU.K+(THU.K)(HCNRN.K/100)-EXLCTU.K
*8020  PHCHCM.K=CLIP(0,(RHCHR.K)(EINHIM.K+NTINHI.K)/(NINHIM.K+NTINHI.K),0
 X     ,(RHCHR.K)(EINHIM.K+NTINHI.K))
*8021  MCHPPR.K=MAX(0,(HUOCMI.K)(PMCCRN.K-(PMCCRN.K)(1-PMCHCM.K)(CLIP(1,0
 X     ,1,PSPIMI.K))+(APMCCR.K)(PMCHCM.K-1)(CLIP(1,0,PSPIMI.K,1))))
 8022  APMCCR.K=CLIP(APMCR2.K,APMCR1.K,TIME.K,120)
 8023  APMCR1.K=MAX(0,(EXFHU.K-FHU.K)(MMIHFR.K)/HUOCMI.K)
 8024  APMCR2.K=MAX(0,(EXFHU.K-FHU.K)(1-GCHCN.K)(PCMCHC.K)/HUOCMI.K)
*8025  PMCHCM.K=CLIP(0,(RMCHR.K)(EINMIM.K+NTINMI.K)/(NINMIM.K+NTINMI.K),0
 X     ,(RMCHR.K)(EINMIM.K+NTINMI.K))
*8026  LCHPPR.K=MAX(0,(HUOCLI.K)(PLCCRN.K-(PLCCRN.K)(1-PLCHCM.K)(CLIP(1,0
 X     ,1,PSPILI.K))+(APLCCR.K)(PLCHCM.K-1)(CLIP(1,0,PSPILI.K,1))))
 8027  APLCCR.K=CLIP(0,APLCR1.K,TIME.K,120)
 8028  APLCR1.K=MAX(0,(EXFHU.K-FHU.K)(MLIHFR.K)/HUOCLI.K)
*8029  PLCHCM.K=CLIP(0,(RLCHR.K)(EINLIM.K+NTINLI.K)/(NINLIM.K+NTINLI.K),0
 X     ,(RLCHR.K)(EINLIM.K+NTINLI.K))
```

```
*8030  LCHNLG.K=MAX(0,(HUOCLI.K)(GLCCRN.K+(AGLCCR.K)(GLCHCM.K)))
 8031  AGLCCR.K=STEP(AGLCR2.K,120)
 8032  AGLCR2.K=MAX(0,(EXFHU.K-FHU.K)(GCHCN.K)(GCLCHC.K)/HUOCLI.K)

*8033  GMCHCM.K=TABHL(GMCHCT,RUFOCR.K,0,5,1)
 8034  GMCHCT*=-1/0/0.5/1/1.5/2

*8035  MCHNLG.K=MAX(0,(HUOCMI.K)(GMCCRN.K+(AGMCCR.K)(GMCHCM.K)))
 8036  AGMCCR.K=STEP(AGMCR2.K,120)
 8037  AGMCR2.K=MAX(0,(EXFHU.K-FHU.K)(GCHCN.K)(GCMCHC.K)/HUOCMI.K)

*8038  GLCHCM.K=TABHL(GLCHCT,RUFOCR.K,0,5,1)
 8039  GLCHCT*=-1/0/0.7/1.3/1.9/2.5

 8040  HCHNLG.K=MAX(0,(HUOCHI.K)(GHCCRN.K+(AGHCCR.K)(GHCHCM.K)))
 8041  AGHCCR.K=0
 8042  GHCHCM.K=0
```

The model distinguishes between three types of housing units: High, Medium and Low-Cost. Housing units may be constructed by both the Private and the Public Sectors. It is assumed that the former sector may construct housing units of all three types while the latter sector only Medium and Low-Cost. When only the Private Sector is in operation — as it has been the case up to 1920 — the normal construction rate for each type of housing is the exogenously provided general construction rate modified slightly so as to take into account relevant intergroup changes resulting from ageing and deterioration. When both Sectors are in operation (1920-1970), the corresponding normal construction rates are functions of both the exogenously provided general construction rate and the also exogenously provided contribution of each sector towards the construction of each housing type (eqs. 8000-8014).

Equations 8015-8020 generate the number of High-Cost housing units planned for construction by the Private Sector as a funtion of the appropriate normal rate and the demand for this type of housing. In certain very rare cases of extremely large surplus of High-Cost Houses and almost negligible demand, negative planned construction may be generated by the model. To prevent this from happening, equation 8015 sets zero as the lower limit for the number of High-Cost Houses planned for construction by the Private Sector. The model assumes that in the case of a city with demand higher than normal the net extra housing required is proportional not to the normal rate but to a modified one (APHCCR); this takes into account only the Fit Houses required for High-Income Heads arriving from outside the city. The effect of demand on the planned construction of High-Cost Houses by the Private Sector is expressed by the corresponding construction multiplier (eq. 8020). This is a function of both expected demand and adequacy of the existing stock. The same approach is followed for the generation of construction plans by the Private Sector for Medium-Cost Housing Units (eqs. 8021-8025) and Low-Cost Housing Units (eqs. 8026-8029).

Equation 8030 generates the number of Low-Cost Housing Units planned for construction by the Public Sector as a function of the appropriate normal rate and the need for Low-Cost Housing. Need for housing is expressed as a function of the fraction of families occupying Unfit Houses. The effect of housing needs on the construction plans is expressed by the corresponding construction multiplier (eqs. 8033-8034). Asimilar approach is followed for the generation of construction plans by the Public Sector for Medium-Cost Housing Units (eqs. 8035-8039).

8.8.2 Industrial Construction Plans

The following set of equations simulate the process of industrial construction planning.

```
* 8200  IBCNPL.K=MAX(0,((IBOCNI.K)(NIAF)+(IBOCMI.K)(MIAF))((ICNRN.K/100)+(
  X     AIBCNR.K)(IBCNM.K-1))+(FIB.K)(IBAM.K))

* 8201  ICNRN.K=NIINRN.K
* 8202  AIBCNR.K=ANIINR.K

* 8203  IBCNM.K=TABHL(IBCNMT,PSPINI.K,0,2,0.1)
* 8204  IBCNMT*=-4.00/-3.85/-3.70/-3.60/-3.40/-3.20/-2.00/-1.50/-0.30/0.80
  X     /1.00/1.10/1.20/1.40/1.80/3.00/3.55/3.70/3.85/3.90/4.00

* 8205  IBAM.K=TABHL(IBAMT,RIBR.K,0.5,5,0.5)
* 8206  IBAMT*=1/0/-0.33/-0.5/-0.6/-0.67/-0.71/-0.75/-0.78/-0.8
```

Unlike the case of housing units, industrial buildings have been constructed exclusively by the Private Sector during the major part of the period covered by the model. Although the involvement of the Public Sector has been increasing in recent years not enough data is available for a realistic explicit modelling. Under those circumstances the model assumes that industrial buildings are constructed by the Private Sector only. The increasing use of industrial buildings' provision as a positive inducement for industries and its eventual inclusion in the model in this capacity were discussed in section 7.3.4.

The effect of industrial construction by the Public Sector on the development of a city may also be tested through the "Industrial Buildings Construction Program" which has been built into the model. More details about this program are given in the Control Sector.

Equation 8200 generates the number of industrial buildings planned for construction during a given period as a function of the exogenously provided normal industrial construction rate and the demand for industrial buildings. In the case of a city with demand higher or lower than normal the net additional construction is proportional not to the normal construction rate but to a modified one (eq. 8202); this is identical to the modified rate used for the net additional inflow of industrial units. The effect of demand on the construction of industrial buildings is expressed through the corresponding constuction multiplier (eqs. 8203,8204). For the purposes of the model this is taken as a function of the Specific Image as perceived by industrial units. Vacancies of industrial buildings are also taken into account through the Industrial Buildings Adequacy Multiplier (eqs. 8205,8206).

8.8.3 Realisation of Construction Plans

I have so far generated the total number of housing units and industrial buildings planned for construction. The realisation of those plans is subject to two constraints: the city's financial capability, affecting plans by the Public Sector only, and the availability of construction workers,affecting plans by both sectors. The following set of equations simulate the plan-realisation process.

```
 8400  THPPR.K=HCHPPR.K+MCHPPR.K+LCHPPR.K+0.000001

 8401  THNDLG.K=MCHNLG.K+LCHNLG.K+0.000001
*8402  GCNRND.K=THNDLG.K/THU.K
 8403  GCNRN.K=(THU.K)(GCHCN.K)(HCNRN.K/100)/THU.K
 8404  RGCNRN.K=SWITCH(1,GCNRND.K/GCNRN.K,GCNRN.K)
*8405  GCNRFS.K=(GCNRND.K)(CNEAM.K)

*8406  CNEAM.K=TABHL(CNEAMT,EXACNM.K/ENCNM.K,0,1,1)
*8407  CNEAMT*=0/1

*8408  THPLG.K=(THU.K)(GCNRFS.K)
 8409  THCNPL.K=THPPR.K+THPLG.K
 8410  HCNRND.K=MAX(0,THCNPL.K/THU.K)
 8411  ICNRND.K=MAX(.000001,IBCNPL.K/((IBOCNI.K)(NIAF)+(IBOCMI.K)(MIAF)))
 8412  TCNRN.K=(0.5)(HCNRN.K/100)+(0.5)(ICNRN.K/100)
*8413  TCNRND.K=(0.5)(HCNRND.K)+(0.5)(ICNRND.K)
 8414  RCNRND.K=TCNRND.K/TCNRN.K
*8415  TCNRFS.K=(TCNRND.K)(CWAVM.K)

*8416  CWAVM.K=TABHL(CWAVMT,1/SJR.K,0,1,1)
*8417  CWAVMT*=0/1

*8418  HCNRFS.K=((TCNRFS.K)((0.5)(HCNRND.K)/TCNRND.K))/0.5
*8419  ICNRFS.K=((TCNRFS.K)((0.5)(ICNRND.K)/TCNRND.K))/0.5
*8420  THCN.KL=(THCNPL.K)(HCPRM.K)

*8421  HCPRM.K=TABHL(HCPRMT,HCNRFS.K/HCNRND.K,0,1,1)
*8422  HCPRMT*=0/1

*8423  IBCN.KL=(IBCNPL.K)(ICPRM.K)+IBCNPG.K

*8424  ICPRM.K=TABHL(ICPRMT,ICNRFS.K/ICNRND.K,0,1,1)
*8425  ICPRMT*=0/1

*8426  THCNPR.KL=(THPPR.K)(HCPRM.K)
*8427  THCNLG.KL=(THPLG.K)(HCPRM.K)
 8428  HCHCPR.KL=(HCHPPR.K)(HCPRM.K)
 8429  MCHCPR.KL=(MCHPPR.K)(HCPRM.K)
 8430  LCHCPR.KL=(LCHPPR.K)(HCPRM.K)
 8431  HCHCLG.KL=(HCHNLG.K)(HCPRM.K)+HCHCPG.K
 8432  MCHCLG.KL=(MCHNLG.K)(HCPRM.K)+MCHCPG.K
 8433  LCHCLG.KL=(LCHNLG.K)(HCPRM.K)+LCHCPG.K
```

Equation 8402 computes the construction rate which must be achieved by the Public Sector if all its housing requirements are to be met. Equation 8405 computes the feasible construction rate as a function of the required rate and the level of expenditure available for housing. The model assumes that the construction needed by the local government can be achieved only if the expenditure available for housing construction exceeds the required level. Both the required and available expenditure levels are calculated in the Taxation /Expenditure Sector; their effect on the government construction rate is described by equations 8406, 8407 and illustrated in the following Figure.

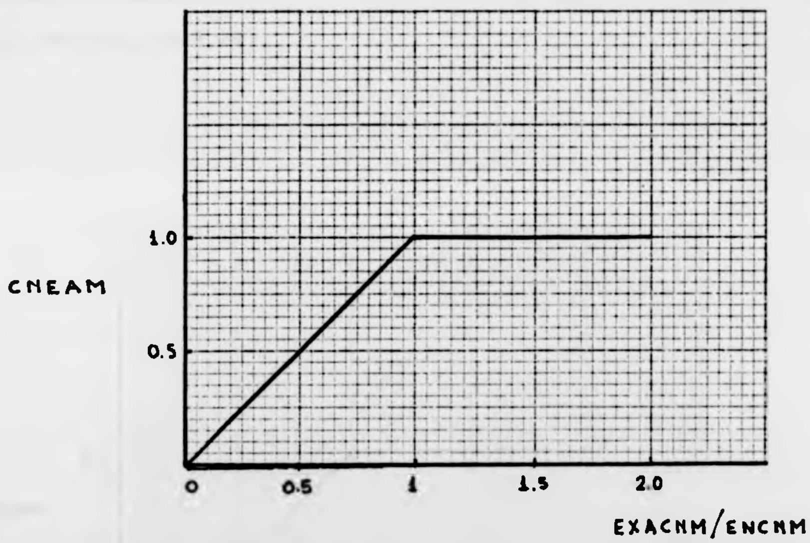

Figure 8.23

The feasible construction rate by the Public Sector is in turn used inequation 8408 for the generation of the maximum number of housing units whose construction may be financed.

Equation 8413 generates the total construction rate which must be achieved if all the construction plans for houses — by both Sectors — and industrial buildings are to be realised. In defining this rate residential and industrial construction are considered as carrying equal weight. Achievement of this rate, however, is subject to the availability of construction workers. The model assumes that all construction workers are skilled and equation 8415 generates the total feasible construction rate as a function of the required rate and the availability of skilled workers. As long as the number of skilled workers equals or exceeds the number of offered jobs, the required total construction rate may be attained. In the opposite case only a fraction of the required rate is feasible and the unsatisfied demand is proportional to the skilled job vacancy fraction (eqs. 8416, 8417 and Figure 8.24).

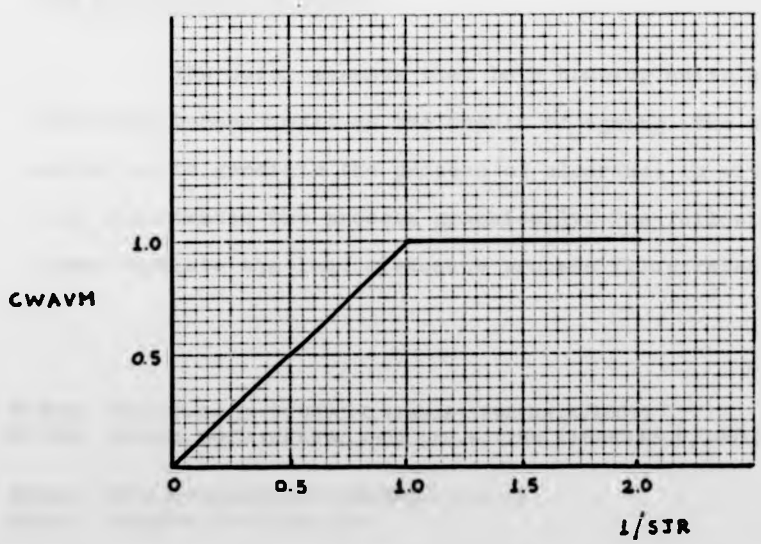

Figure 8.24

Following the derivation of the total feasible construction rate, specific feasible construction rates for houses and industrial buildings are computed (eqs. 8418, 8419) and they are used to generate the number of houses and industrial buildings actually constructed (eqs. 8420, 8423). The necessary condition for the construction of all planned houses is that the feasible housing construction rate is at least equal to the required one (eqs. 8421, 8422). The same is true for the case of industrial buildings (eqs. 8424, 8425).

Equations 8426 and 8427 give the number of housing units constructed by the Private and Public Sectors while the remaining equations classify the constructed houses according to their cost. In the case when the construction of new houses cannot meet the total demand the number of houses built from every type is proportional to demand.

8.9 LAND CLEARANCE SECTOR

The model assumes that both housing units and industrial buildings become unfit as the result of ageing. The objective of this sector is to generate the process of clearance in either case. Figure 8.25 illustrates the process graphically. The following set of equations simulate the land clearance process illustrated in Figure 8.25.

```
* 9000  UHCLPP.K=MIN(UFHUVC.K,(THU.K)(PHCLRN.K/100))
* 9001  UHCLNG.K=MIN(UFHUVC.K-UHCLPP.K,(THU.K)(GHCLRN.K/100)(HCLM.K))

*9002   HCLM.K=TABHL(HCLMT,RUFHFR.K,0,4,1)
*9003   HCLMT*=-1/1/1.3/1.7/2

*9004   IBCLPP.K=MIN(UFIB.K,(TIB.K)(PICLRN.K/100))
*9005   IBCLNG.K=MIN(UFIB.K-IBCLPP.K,(TIB.K)(GICLRN.K/100)(ICLM.K))

*9006   ICLM.K=TABHL(ICLMT,RUFIBF.K,0,4,1)
*9007   ICLMT*=-1/1/1.3/1.7/2

*9008   UHCLP.KL=(UHCLPP.K)(AXMULT)
*9009   IBCLP.KL=(IBCLPP.K)(AXMULT)

*9010   GHCRND.K=MAX(0.000001,UHCLNG.K/THU.K)
*9011   GICRND.K=MAX(0.000001,IBCLNG.K/TIB.K)
*9012   TGCRND.K=(0.5)(GHCRND.K)+(0.5)(GICRND.K)
 9013   TGCLRN.K=(0.5)(GHCLRN.K/100)+(0.5)(GICLRN.K/100)
 9014   RGCLRN.K=CLIP(1,TGCRND.K/TGCLRN.K,0,TGCLRN.K)
*9015   TGCRFS.K=(TGCRND.K)(CLEAM.K)
```

true for the case of industrial buildings (eqs. 8424, 8425).

Equations 8426 and 8427 give the number of housing units constructed by the Private and Public Sectors while the remaining equations classify the constructed houses according to their cost. In the case when the construction of new houses cannot meet the total demand the number of houses built from every type is proportional to demand.

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```
* 9000  UHCLPP.K=MIN(UFHUVC.K,(THU.K)(PHCLRN.K/100))
* 9001  UHCLNG.K=MIN(UFHUVC.K-UHCLPP.K,(THU.K)(GHCLRN.K/100)(HCLM.K))

*9002  HCLM.K=TABHL(HCLMT,RUFHFR.K,0,4,1)
*9003  HCLMT*=-1/1/1.3/1.7/2

*9004  IBCLPP.K=MIN(UFIB.K,(TIB.K)(PICLRN.K/100))
*9005  IBCLNG.K=MIN(UFIB.K-IBCLPP.K,(TIB.K)(GICLRN.K/100)(ICLM.K))

*9006  ICLM.K=TABHL(ICLMT,RUFIBF.K,0,4,1)
*9007  ICLMT*=-1/1/1.3/1.7/2

*9008  UHCLP.KL=(UHCLPP.K)(AXMULT)
*9009  IBCLP.KL=(IBCLPP.K)(AXMULT)

*9010  GHCRND.K=MAX(0.000001,UHCLNG.K/THU.K)
*9011  GICRND.K=MAX(0.000001,IBCLNG.K/TIB.K)
*9012  TGCRND.K=(0.5)(GHCRND.K)+(0.5)(GICRND.K)
 9013  TGCLRN.K=(0.5)(GHCLRN.K/100)+(0.5)(GICLRN.K/100)
 9014  RGCLRN.K=CLIP(1,TGCRND.K/TGCLRN.K,0,TGCLRN.K)
*9015  TGCRFS.K=(TGCRND.K)(CLEAM.K)
```

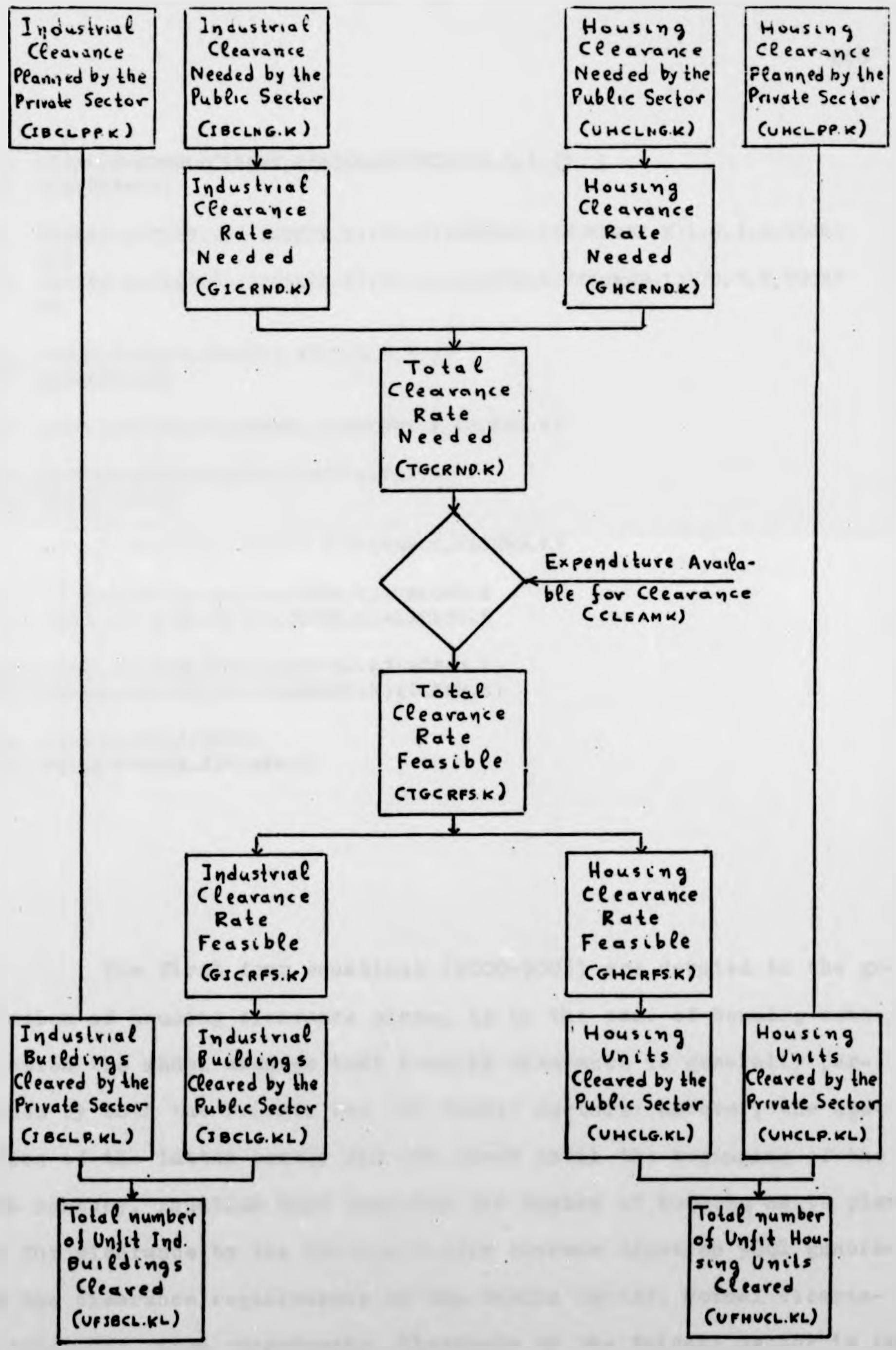

Figure 8.25

Land Clearance Sector

```
*9016  CLEAM.K=TABHL(CLEAMT,EXACLM.K/ENCLM.K,0,1,1)
*9017  CLEAMT*=0/1

*9018  GHCRFS.K=CLIP(0,((TGCRFS.K)((0.5)(GHCRND.K)/TGCRND.K))/0.5,0,TGCRN
 X     D.K)
*9019  GICRFS.K=CLIP(0,((TGCRFS.K)((0.5)(GICRND.K)/TGCRND.K))/0.5,0,TGCRN
 X     D)

*9020  HCPEM.K=TABHL(HCPEMT,AXV3.K,0,1,1)
*9021  HCPEMT*=0/1

*9022  AXV3.K=SWITCH(0,GHCRFS.K/GHCRND.K,GHCRND.K)

*9023  ICPEM.K=TABHL(ICPEMT,AXV4.K,0,1,1)
*9024  ICPEMT*=0/1

*9025  AXV4.K=SWITCH(0,GICRFS.K/GICRND.K,GICRND.K)

*9026  UHCLG.KL=(UHCLNG.K)(HCPEM.K)+UHCLPG.K
*9027  IBCLG.KL=(IBCLNG.K)(ICPEM.K)+IBCLPG.K

 9028  UFHUCL.KL=UHCLPP.K+(UHCLNG.K)(HCPEM.K)
 9029  UFIBCL.KL=IBCLPP.K+(IBCLNG.K)(ICPEM.K)

 9030  RIAR.K=FHU.K/TIU.K
 9031  RRIAR.K=RIAR.K/RIARN.K
```

The first four equations (9000-9003) are devoted to the generation of housing clearance plans. As in the case of housing construction the model assumes that housing clearance is generally performed by both the Private and the Public Sectors; however, the operation of the latter sector did not start until the beginning of the 20th century. Equation 9000 computes the number of housing units planned for clearance by the Private Sector whereas equation 9001 generates the clearance requirements of the Public Sector. Normal clearance rates are given exogenously. Clearance by the Private Sector is taken as simply proportional to the level of residential activity. Clearance by the Public Sector, on the other hand,is influenced mainly by the proportion of Unfit Housing Units; their effect on the clearance plans is expressed by equations 9002,9003. For the purposes of the model a simple relationship is assumed which is also illustrated in Figure 8.26.

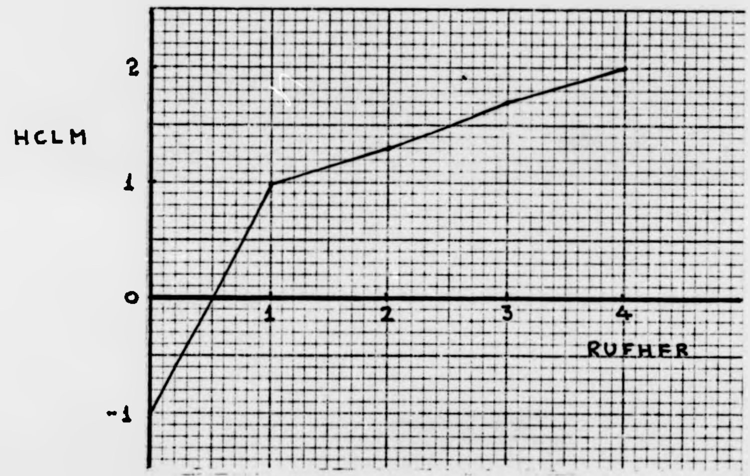

Figure 8.26

The same procedure is followed for the generation of industrial demolition requirements (eqs. 9004-9007). Normal industrial clearance rates are given exogenously. Furthermore the model assumes that industrial clearance by the Private Sector is simply proportional to the level of industrial activity in the given city while clearance by the Public Sector is also influenced by the proportion of Unfit Industrial Buildings. The effect of the latter factor on the clearance plans is described by equations 9006, 9007 and it is also illustrated in Figure 8.27.

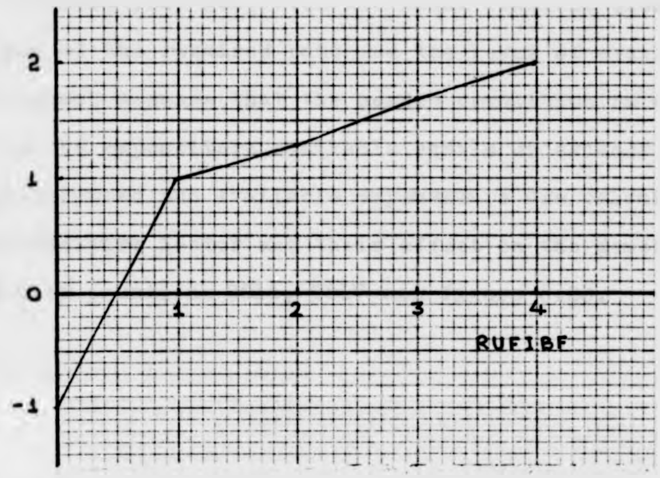

Figure 8.27

Unlike the case of construction, availability of skilled workers is not considered as a basic requirement in the case of land clearance. Hence the demolition planned by the Private Sector is always carried out (eqs. 9008, 9009) while the demolition planned by the Public Sector is subject to the city's financial capabilities.

Equation 9010 generates the clearance rate which must be achieved if all the housing demolition requirements by the Public Sector are to be met. Equation 9011 repeats this process for the case of industrial buildings. Finally equation 9012 computes the total clearance rate required by the Public Sector. In defining this rate residential and industrial clearance are considered as carrying the same weight.

Equation 9015 generates the total feasible clearance rate as a function of the required rate and the level of available expenditure. The model assumes that the needed demolition rate can be achieved only if the expenditure available equals or exceeds the required level. Both required and available expenditure are calculated in the Taxation/Expenditure Sector and their effect on the demolition rate is described by equations 9016, 9017 and Figure 8.28.

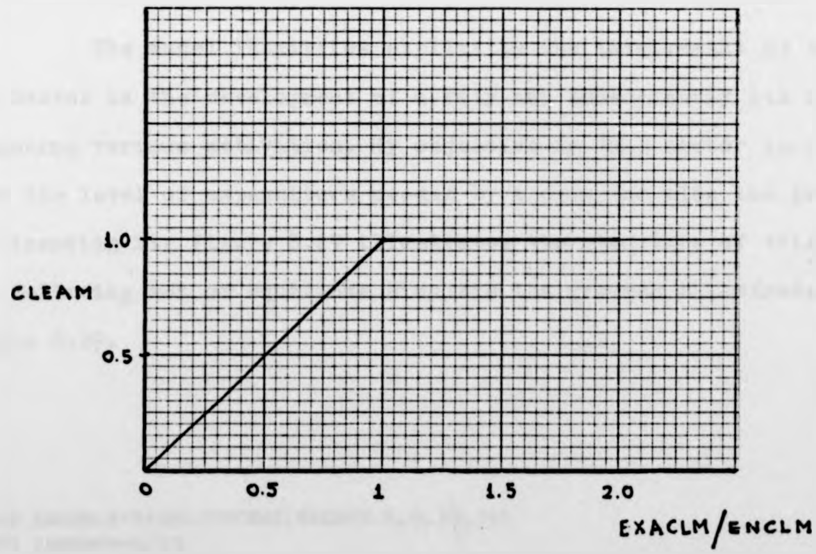

Figure 8.28

Following the derivation of the total feasible clearance rate specific rates concerning houses and industrial buildings respectively are computed (eqs. 9018, 9019). The model assumes that the necessary condition for the realisation of the housing clearance plans is that the feasible clearance rate must be greater than or equal to the required rate. On the basis of this assumption a Housing Clearance Plans Execution Multiplier is defined (eqs. 9020-9022). The same procedure is followed in the case of industrial buildings and a similar multiplier is defined (eqs. 9023-9025). The two multipliers are then used in order to generate the number of houses and industrial buildings which are actually cleared by the Public Sector during a given period (eqs. 9026, 9027).

8.10 TAXATION/EXPENDITURE SECTOR

The model identifies explicitly the involvement of the Public Sector in the development of a city and consequently its role in financing various activities. My objective in this sector is to generate the level of expenditure needed by a city and also the process of financing it. Figure 8.29 illustrates the structure of this sector. The following set of equations simulate the process illustrated in Figure 8.29.

```
* 10000 ENCNM.K=TABHL(ENCNMT,RGCNRN.K,0,10,10)
* 10001 ENCNMT*=0/10

* 10002 ENCLM.K=TABHL(ENCLMT,RGCLRN.K,0,10,10)
* 10003 ENCLMT*=0/10

* 10004 EXNDM.K=(CNWT)(ENCNM.K)+(CLWT)(ENCLM.K)
  10005 PCEXND.K=(PCEXN.K)(EXNDM.K)
* 10006 TEXND.K=(TOTP.K)(PCEXND.K)


* 10007 HRTV.K=(LCHU.K)(RVLCHU)+(MCHU.K)(RVMCHU)+(HCHU.K)(RVHCHU)
* 10008 IRTV.K=(NIU.K)(RVNIU)+(MIU.K)(RVMIU)+(DIU.K)(RVDIU)
* 10009 TRTV.K=HRTV.K+IRTV.K

* 10010 GCEX.K=(TRTV.K)(GCEXN.K/100)+(TRTV.K)(GCEXM.K)(CLIP(0,1,SWT1,TIME.
  X      K))+FNASPG.K
```

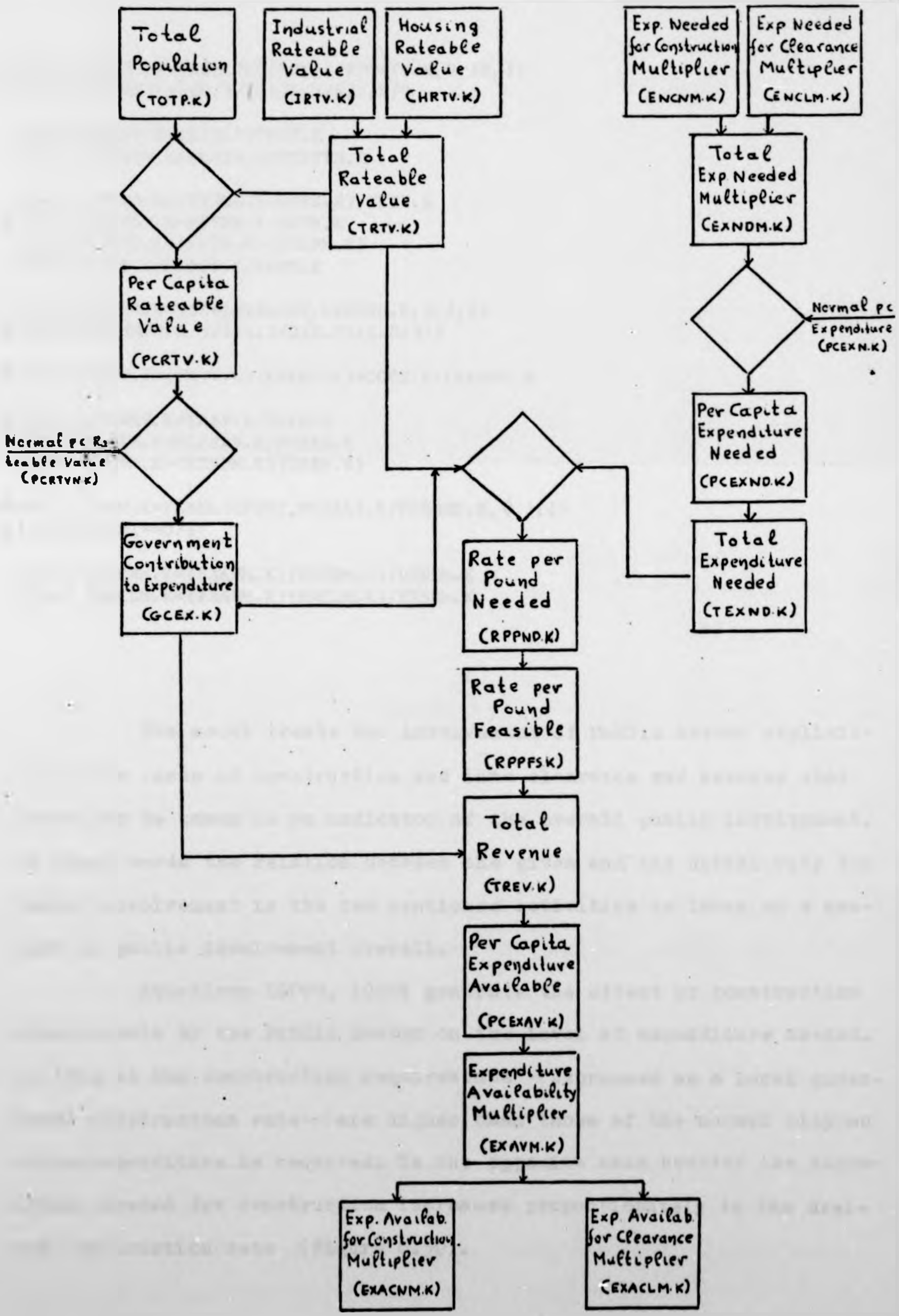

Figure 8.29 **Taxation/Expenditure Sector**

```
*10011 GCEXM.K=TABHL(GCEXMT,1/RPCRTV.K,0,10,1)
*10012 GCEXMT*=0/0/1/2/3/4/5/6/7/8/9

 10013 PCRTV.K=TRTV.K/TOTP.K
 10014 RPCRTV.K=PCRTV.K/PCRTVN.K

 10015 RPPND.K=(TEXND.K-GCEX.K)/TRTV.K
*10016 RRPPND.K=RPPND.K/RPPN.K
 10017 RPPFS.K=(RPPN.K)(TXAPM.K)
 10018 RRPP.K=RPPFS.K/RPPN.K

*10019 TXAPM.K=TABHL(TXAPMT,RRPPND.K,0,7,1)
*10020 TXAPMT*=0.1/1/1.5/2/2.55/2.8/3/3

*10021 TREV.K=(TRTV.K)(RPPFS.K)+GCEX.K+FNASPG.K

*10022 PCEXAV.K=TREV.K/TOTP.K
 10023 RPCEX.K=PCEXAV.K/PCEXN.K
 10024 EXAVM.K=(EXNDM.K)(CFSM.K)

*10025 CFSM.K=TABHL(CFSMT,PCEXAV.K/PCEXND.K,0,1,1)
*10026 CFSMT*=0/1

 10027 EXACNM.K=(EXAVM.K)(ENCNM.K)/EXNDM.K
 10028 EXACLM.K=(EXAVM.K)(ENCLM.K)/EXNDM.K
```

The model treats the involvement of Public Sector explicitly in the cases of construction and land clearance and assumes that those may be taken as an indicator of the overall public involvement. In other words the relation between the given and the normal city for public involvement in the two mentioned activities is taken as a measure of public involvement overall.

Equations 10000, 10001 generate the effect of construction requirements by the Public Sector on the level of expenditure needed. As long as the construction requirements —expressed as a local government construction rate— are higher than those of the normal city no extra expenditure is required. In the opposite case however the expenditure needed for construction increases proportionately to the desired construction rate (Figure 8.30).

a city had been minimal and in no way aiming towards a redistribution of economic resources and social amenities. Changes in conditions and attitudes however, which have been discussed in Chapter 5, have led to a much more positive involvement of the Public Sector. On the basis of this evidence equation 10010 generates the government contribution to the financing of a city's activities. The first term expresses Public Sector contribution as simply proportional to the level of rate receipts. The second term expresses the aim of central government intervention as the increase of the amount of the Per Capita Rateable Value to the normal level whenever this is necessary. Finally the third term represents a control program which may be used for testing the effect of increased government intervention on the development of a city; more details about this term are given in the Control Sector. Equation 10010 is constructed in such a way that the last two terms may be activated during selected time periods.

Equations 10011, 10012 generate the influence of Relative Per Capita Rateable Value on the degree of central government contribution to expenditure. For the purposes of the model a simple propor-

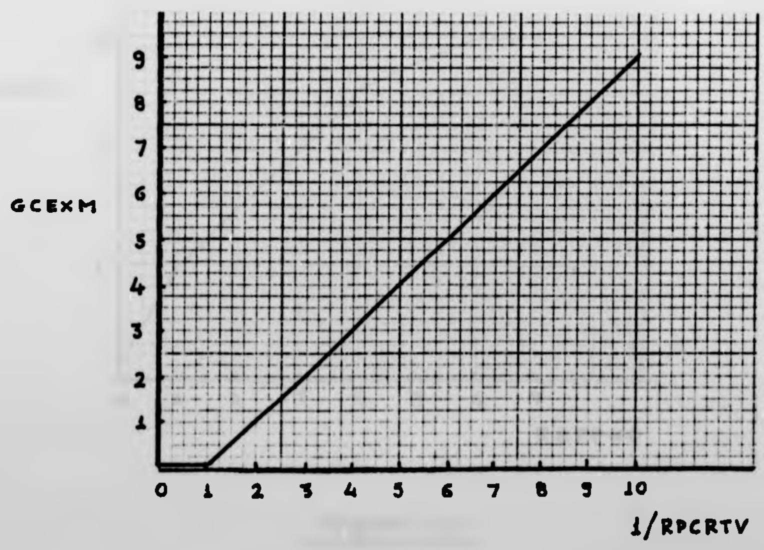

Figure 8.31

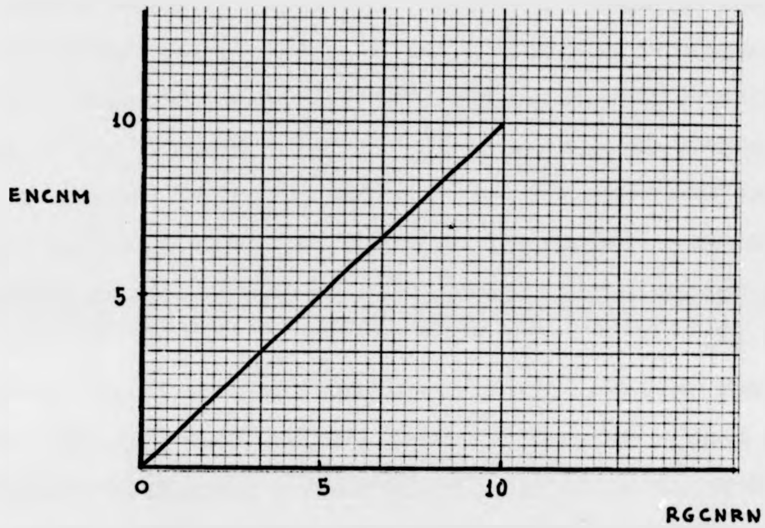

Figure 8.30

The effect of clearance requirements on the expenditure needed is expressed in the same way (eqs. 10002, 10003) and finally equation 10004 derives the combined effect of both activities. Construction and clearance carry different weights in defining the total level of expenditure needed. Those weights are given exogenously.

Having generated the total expenditure needed (eq. 10006) the model moves on to the process of financing it. It distinguishes between two income sources: rate receipts and external contributions (mainly Government grants and loans). Equations 10007-10009 generate the Total Rateable Value in the city; the values of housing and industrial units of the different types, which are used in those equations, are given exogenously. Empirical evidence suggests that until well into the 20th century public involvement in the development of a city had been minimal and in no way aiming towards a redistribution of economic resources and social amenities. Changes in conditions and attitudes however, which have been discussed in Chapter 5, have led to a much more positive involvement of the Public Sector. On the basis of this evidence equation 10010 generates the government contribution to the financing of a city's activities. The first term expresses Public Sector contribution as simply proportional to the level of rate receipts. The second term expresses the aim of central government intervention as the increase of the amount of the Per Capita Rateable Value to the normal level whenever this is necessary. Finally the third term represents a control program which may be used for testing the effect of increased government intervention on the development of a city; more details about this term are given in the Control Sector. Equation 10010 is constructed in such a way that the last two terms may be activated during selected time periods.

Equations 10011, 10012 generate the influence of Relative Per Capita Rateable Value on the degree of central government contribution to expenditure. For the purposes of the model a simple propor-

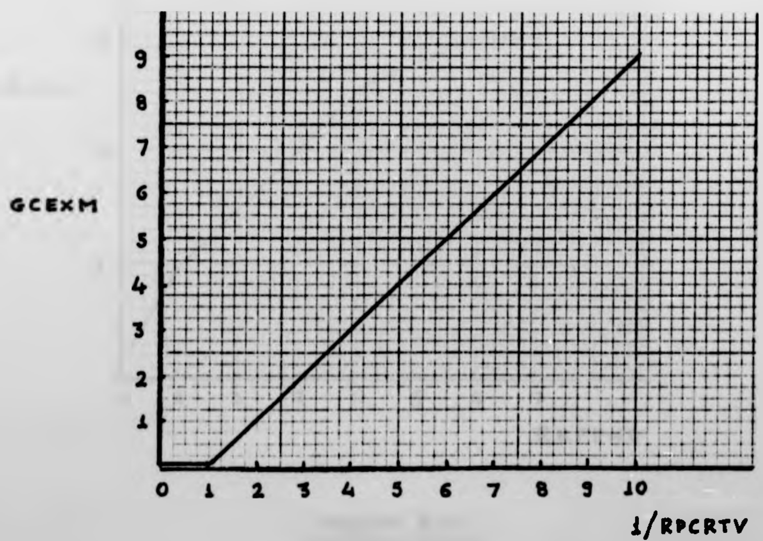

Figure 8.31

tional relationship is adopted which is also illustrated in Figure 8.31.

On the basis of the Total Expenditure Needed and the Total Rateable Value the model computes the rate per pound required for the financing of all necessary activities (eq. 10016). Imposing the required tax rate, however, is not always possible for a variety of reasons. The modelling of the relationship between the needed and imposed tax rate requires in general an understanding of the overall political climate as well as legislative powers of the relevant local authority. For the purposes of the model however, I simply assume that the probability of full assessment of the required tax rate depends on its deviance from the corresponding normal rate; in other words the higher the required rate, the more difficult its full assessment. The relationship used by the model is illustrated in equations 10019, 10020 and Figure 8.32.

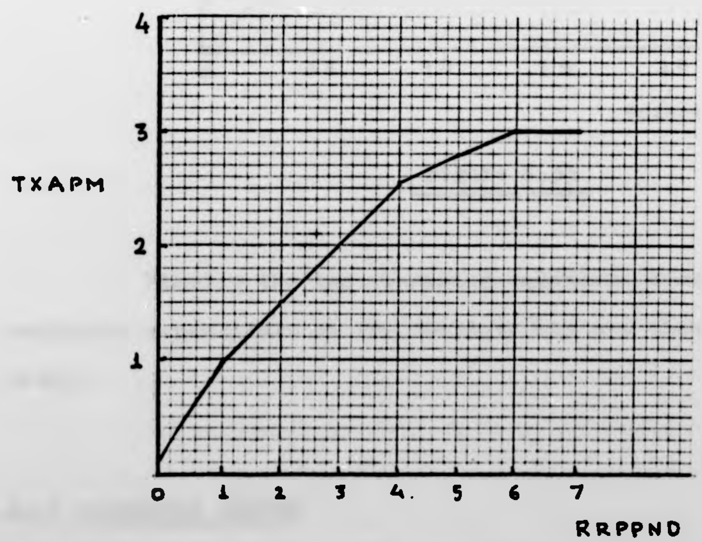

Figure 8.32

The next two equations generate the total city revenue and the Per Capita Expenditure Available. As long as the Per Capita Expenditure Available is greater than the required all the expenditure plans are realised. In the opposite case only a partial satisfaction of the demand is achieved. Figure 8.33 illustrates this relationship which is also described by equations 10025, 10026.

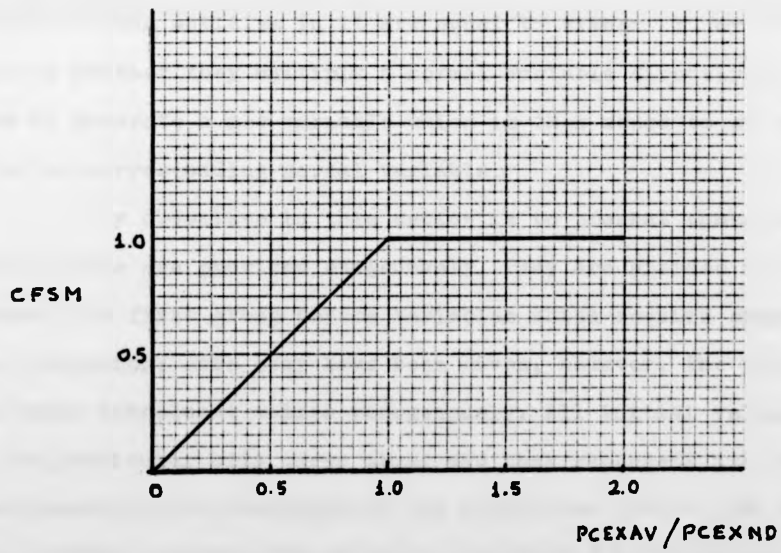

Figure 8.33

Finally the two remaining equations describe the effect of available expenditure on the construction and clearance plans respectively.

8.11 EXOGENOUS SECTOR

For the purposes of the model movement of people and industries has been considered as a function of the Specific Image of the city as perceived by the various groups of potential movers. Specific Images express the relative attractiveness of a given city as compared to that of the normal city. Similarly, changes in the various entities of the given city have been expressed as functions of the corresponding changes in the normal city and several multipliers have been introduced for modelling the form of those functions. It is assumed that the Basic and Specific Images of the normal city are all equal to 1. Furthermore all the multipliers controlling the generations of urban entities in it are equal to either 1 or 0 depending on whether they multiply a normal variable directly or they are used to generate a new variable which is then added to or subtracted from the corresponding normal variable.

My objective in this sector is to present those variables whose values are provided exogenously. They are divided into four groups. The first group covers variables which require exogenous initial condition; once they have been given, however, the model generates their subsequent values endogenously. All initial values depend on the particular city under study and they represent its state of development at the beginning of the simulation period. The second group covers variables which may be considered as expressing general national trends; therefore they are independent of the particular city and indeed they are taken as identical for the normal city and any other city. Variables of this group include family size, death rate, marriage rate, national industrial activity etc. The third group includes variables which may be considered as expressing local characteristics and hence they are generally different from city to city. Variables of this group concern accessibility to markets and resources, land availability etc. Finally, the fourth group covers variables which provide the general trend of development of the normal city by expressing selected aspects of it. When the model is applied to a particular city those variables form the basis of comparison between the given and the normal city. More precisely they are directly involved in the derivation of the Specific Images of the given city as well as the derivation of the different multipliers controlling the generation of urban activities in it. Variables of this group include normal housing ratios, normal employment ratios, normal tax-rate etc.

8.11.1 Variables Requiring Initial Value

Variables requiring exogenous initial values may be classified into four categories. The first contains the Basic and Specific Images of the given city while the remaining three include variables concerning population, industrial activity and residential activity respectively. A list of all variables requiring initial value is given below.

1. Basic and Specific Images

   BI : Basic Image

   PSPIAU: Perceived Specific Image for Active Unskilled

   PSPIAS: Perceived Specific Image for Active Skilled

   PSPIAP: Perceived Specific Image for Active Professionals

   PSPINI: Perceived Specific Image for New Industries

2. Variables Concerning Population

   AUH: Active Unskilled Heads

   ASH: Active Skilled Heads

   APH: Active Professional Heads

   RH : Retired Heads

3. Variables Concerning Industrial Activity

   NIU : New Industrial Units

   MIU : Mature Industrial Units

   DIU : Declining Industrial Units

CJ : Construction Jobs

FIB : Fit Industrial Buildings

UFIB: Unfit Industrial Buildings

4. Variables Concerning Residential Activity

HCHU: High-Cost Housing Units

MCHU: Medium-Cost Housing Units

LCHU: Low-Cost Housing Units

UFHU: Unfit Housing Units

The initial values of all variables listed above depend on the particular city to which the model is applied and they will be given by means of constant equations i.e.

AUH = <VALUE>

Therefore equation numbers 11000-11018 will be reserved for equations providing initial values.

8.11.2 Variables Expressing National Trends

My main objective in modelling the process of a city's development is to obtain an assessment of its relative growth as compared to that of the normal city. Therfore all variables which are considered identical for the normal city and the one under consideration may be chosen arbitrarily. In such a case the model will simulate the relative trend of the city's development but the results will be unrealistic in absolute terms. A second approach which will lead to more realistic results employs any available data for the derivation of reliable estimators for those exogenous variables. I have used the latter approach. Details about the estimation of those variables are given in Appendix 2. At this stage I simply present those variables in the form they are used in the model and in the order they are discussed in Appendix 2.

1. Variables Concerning Population

The following set of equations generate exogenous variables expressing national trends concerning population.

```
*11200 RFS=1.5

*11201 AFS.K=TABHL(AFST,TIME.K,0,170,10)
*11202 AFST*=5.14/5.22/5.30/5.25/5.35/5.41/4.94/4.99/5.12/5.30/5.15/5.06/
 X     4.75/4.32/4.07/3.86/3.83/3.54

 11203 NHEAPF.K=TABHL(NHEAFT,TIME.K,0,170,10)
 11204 NHEAFT*=1.41/1.46/1.41/1.41/1.45/1.51/1.35/1.36/1.29/1.34/1.33/1.3
 X     9/1.25/1.15/1.10/1.05/1.00/0.85

 11205 CPAF.K=TABHL(CPAFT,TIME.K,0,170,10)
 11206 CPAFT*=2.035/2.070/2.095/2.080/2.110/1.95/1.80/1.89/1.95/2.02/1.75
 X     /1.73/1.53/1.19/1.00/0.92/0.96/0.88

*11207 ADR.K=SAMPLE(AX200,10)
*11208 AX200.K=TABHL(AX200T,TIME.K,0,160,10)
*11209 AX200T*=2.14/1.82/1.87/1.97/1.69/1.91/1.92/1.83/1.72/1.49/1.32/1.2
 X     1/0.91/0.65/0.68/0.41/0.53
*11210 ADR=2.14

 11211 RDR.K=SAMPLE(AX201,10)
 11212 AX201.K=TABHL(AX201T,TIME.K,0,160,10)
 11213 AX201T*=9.57/9.57/9.57/9.57/9.57/9.13/9.11/9.35/8.96/8.95/8.45/8.0
 X     7/7.53/7.20/6.65/6.71/6.81
 11214 RDR=9.57

 11215 MPR.K=SAMPLE(AX202,10)
 11216 AX202.K=TABHL(AX202T,TIME.K,0,160,10)
 11217 AX202T*=48.60/48.68/49.12/49.01/48.87/48.98/48.72/48.68/48.66/48.4
 X     5/48.35/48.35/47.71/47.91/48.24/48.03/48.38
 11218 MPR=48.60

 11219 MR.K=SAMPLE(AX203,10)
 11220 AX203.K=TABHL(AX203T,TIME.K,0,160,10)
 11221 AX203T*=9.10/8.90/8.70/8.50/7.20/7.80/8.90/8.90/8.10/6.60/6.55/6.3
 X     5/7.30/7.40/8.60/8.20/7.97
```

```
11222 MR=9.10

11223 RR.K=SAMPLE(AX204,10)
11224 AX204.K=TABHL(AX204T,TIME.K,0,160,10)
11225 AX204T*=1.57/1.65/1.64/1.79/1.88/1.81/1.71/1.72/1.72/1.76/1.82/1.9
X      0/2.10/2.30/2.47/2.48/2.50
11226 RR=1.57

11227 AHINRN=0.45

11228 AUPT.K=TABHL(AUPTT,TIME.K,0,150,50)
11229 AUPTT*=8/7/4/2

11230 ASPT.K=TABHL(ASPTT,TIME.K,0,150,50)
11231 ASPTT*=6/5.25/3/1.5

11232 APPT.K=TABHL(APPTT,TIME.K,0,150,50)
11233 APPTT*=4/3.5/2/1
```

Equation 11200 introduces the size of a family under Retired Head. The model assumes that this remains constant over time and hence it is defined through a constant equation. On the other hand, the size of a family under Active Head is allowed to vary over time. Its value its provided exogenously every ten years and the model generates the intermediate values by interpolation (eqs. 11201, 11202). The form and operation of the TABHL function used for the generation of the Active Family Size has been discussed in Chapter 4.

Equations 11207-11210 generate the death rate for Active Heads (or Active Death Rate). Its value is provided exogenously every ten years and it is kept constant during the next decade. The form and operation of the SAMPLE function used for the generation of the Active Death Rate has also been discussed in Chapter 4.

The remaining equations of this section generate the rest of the exogenous variables in one of the three ways described above.

2. Variables Concerning Industrial Activity

Equations 11234-11264 generate the exogenous variables which express national trends concerning industrial activity in one of the three ways described in the previous section.

```
11234 NIDCRN=1/20
11235 MIDCRN=1/30
11236 DIABRN=1/30

11237 NIAF=1
11238 MIAF=0.5

11239 CJPN=0.06952

11240 NIINRN.K=SAMPLE(AX300,10)
11241 AX300.K=TABHL(AX300T,TIME.K,0,160,10)
11242 AX300T*=2.782/3.980/4.730/4.410/4.760/3.365/4.830/4.240/4.760/3.82
X     0/5.940/1.840/2.693/5.840/4.130/2.880/1.700
11243 NIINRN=2.782

11244 NIPT.K=TABHL(NIPTT,TIME.K,0,150,50)
11245 NIPTT*=4/3.5/2/1

11246 UJIUN.K=TABHL(UJIUNT,TIME.K,0,170,10)
11247 UJIUNT*=5.74/5.72/5.71/5.70/5.69/5.68/5.67/5.66/5.64/5.62/5.60/5.5
X     8/5.56/5.54/5.42/5.29/5.22/5.13

11248 SJIUN=3.48

11249 PJIUN.K=TABHL(PJIUNT,TIME.K,0,170,10)
11250 PJIUNT*=0.78/0.80/0.81/0.82/0.83/0.84/0.85/0.86/0.88/0.90/0.92/0.9
X     4/0.96/0.98/1.10/1.23/1.30/1.39

11251 JPIUN=10

11252 PJINRN.K=SAMPLE(AX301,10)
11253 AX301.K=TABHL(AX301T,TIME.K,0,160,10)
11254 AX301T*=.253/.124/.123/.121/.120/.118/.117/.230/.225/.220/.215/.21
X     1/.206/1.162/1.123/0.555/0.672
11255 PJINRN=.253

11256 PJINN.K=SAMPLE(AX303,10)
11257 AX303.K=TABHL(AX303T,TIME.K,0,160,10)

11258 AX303T*=0.002/0.001/0.001/0.001/0.001/0.001/0.001/0.002/0.002/0.00
X     2/0.002/0.002/0.002/0.012/0.013/0.007/0.009
11259 PJINN=0.002

11260 IBDTRN=1/40

11261 PICLRN=0.125

11262 GICLRN.K=SAMPLE(AX302,10)
11263 AX302.K=TABHL(AX302T,TIME.K,0,160,10)
11264 AX302T*=0/0/0/0/0/0/0/0/0/0/.475/.475/.475/.775/.775/.875/.875
```

3. <u>Variables Concerning Residential Activity</u>

The following equations generate the exogenous variables which express national trends concerning residential activity.

```
11265 LCHDRN=1/70
11266 MCHDRN=1/40
11267 HCHDRN=1/40

11268 HCNRN.K=SAMPLE(AX405,10)
11269 AX405.K=TABHL(AX405T,TIME.K,0,160,10)
11270 AX405T*=1.835/2.195/2.425/2.005/2.005/1.315/1.905/2.205/2.165/1.58
X      5/2.135/1.165/2.135/2.195/2.195/2.205/1.055
11271 HCNRN=1.835

11272 GCHCN.K=SAMPLE(AX400,10)
11273 AX400.K=TABHL(AX400T,TIME.K,0,160,10)
11274 AX400T*=0/0/0/0/0/0/0/0/0/0/0/0/0.30/0.25/0.50/0.60/0.40

11275 PCHCHC.K=SAMPLE(AX401,10)
11276 AX401.K=TABHL(AX401T,TIME.K,0,160,10)
11277 AX401T*=0/0/0/0/0/0/0/0/0/0/0/0/0.24/0.26/0.42/0.5/0.35

11278 PCMCHC.K=SAMPLE(AX402,10)
11279 AX402.K=TABHL(AX402T,TIME.K,0,160,10)
11280 AX402T*=0/0/0/0/0/0/0/0/0/0/0/0/0.76/0.74/0.58/0.5/0.65

11281 GCMCHC.K=SAMPLE(AX403,10)
11282 AX403.K=TABHL(AX403T,TIME.K,0,160,10)
11283 AX403T*=0/0/0/0/0/0/0/0/0/0/0/0/0.25/0.15/0.45/0.5/0.35

11284 GCLCHC.K=SAMPLE(AX404,10)
11285 AX404.K=TABHL(AX404T,TIME.K,0,160,10)
11286 AX404T*=0/0/0/0/0/0/0/0/0/0/0/0/0.75/0.85/0.55/0.5/0.65

11287 PHCLRN=0.125

11288 GHCLRN.K=SAMPLE(AX406,10)
11289 AX406.K=TABHL(AX406T,TIME.K,0,160,10)
11290 AX406T*=0/0/0/0/0/0/0/0/0/0/0.15/0.15/0.15/0.3/0.3/0.35/0.35
```

4. Variables Concerning Public Expenditure

The following set of equations generate the exogenous variables which express national trends concerning public expenditure.

```
11291 CNWT=0.8
11292 CLWT=0.2

11293 GCEXN.K=TABHL(GCEXNT,TIME.K,0,170,10)
11294 GCEXNT*=0.08/0.18/0.21/0.29/0.33/0.54/0.76/0.93/1.99/4.67/7.04/9.7
X     6/28.17/45.16/70.89/93.65/105.03/52.55

11295 RPPN.K=TABHL(RPPNT,TIME.K,0,160,10)
11296 RPPNT*=0.100/0.104/0.108/0.113/0.125/0.142/0.154/0.163/0.200/0.229
X     /0.329/0.433/0.975/0.746/0.858/1.029/2.017

11297 RVLCHU=5
11298 RVMCHU=15
11299 RVHCHU=25

11300 RVNIU=500
11301 RVMIU=300
11302 RVDIU=100
```

8.11.3 Variables Expressing Local Trends

The following four variables express local characteristics and their values depend on the particular city under study:

RACSIX: Relative Accessibility Index

RUPDR : Relative Urban Population Density Ratio

LURF : Land Use Regulation Factor

RRGUN : Relative Regional Unemployment Rate

The values of those indices for a given city are provided exogenously by means of SAMPLE or TABHL functions. Details about their derivation are given in Appendix 2. Equation numbers 11400-11409 will be reserved for the equations expressing local trends.

8.11.4 Variables Expressing Aspects of the Normal City's Development

Simulation and assessment of the development of a given city requires, as I have already explained, the prior knowledge of the development of the normal city. In other words it requires the exogenous provision of certain variables which represent selected aspects of the development of the normal city. Such variables form the basis for comparison between the given and the normal city. Those variables may be obtained as output of the presented model if it is applied to the normal city. The major modifications required for such an application are the following:

(i) Set Basic and Specific Images equal to 1.

(ii) Set all the multipliers equal to either 1 or 0 depending on whether they multiply a normal variable directly or they are used to generate a new variable which is then added to or subtracted from the corresponding normal variable.

(iii) Discard all equations concerning the derivation of multiplip-lier values.

The version of the model which is used to simulate the development of the normal city is given in Appendix 5. I shall be referring to it as the "Normal Version".

Normal initial values are also required for all the level variables. For the purposes of the model the population of the normal city in 1801 is taken as 10,000. On the basis of that population, and also on the basis of the analysis presented in the previuous section and in Appendix 2 the following set of initial values have been chosen:

1. Initial Values Concerning Population

AUH (Active Unskilled Heads) = 1003

ASH (Active Skilled Heads) = 729

APH (Active Professional Heads) = 136

RH (Retired Heads) = 267

2. <u>Initial Values Concerning Industrial Activity</u>

NIU	(New Industrial Units)	= 205
MIU	(Mature Industrial Units)	= 205
DIU	(Declining Industrial Units)	= 0
CJ	(Construction Jobs)	= 286
FIB	(Fit Industrial Buildings)	= 421
UFIB	(Unfit Industrial Buildings)	= 0

3. <u>Initial Values Concerning Residential Activity</u>

HCHU	(High-Cost Housing Units)	= 136
MCHU	(Medium-Cost Housing Units)	= 729
LCHU	(Low-Cost Housing Units)	= 972
UFHU	(Unfit Housing Units)	= 0

Using those initial values as well as the exogenous variables expressing national trends which were presented in the previous section and letting the model run for the period 1801-1971 I simulate the development of the normal city over that period.

Detailed Tables giving the values of the selected output variables can be found in Appendix 2. At this point I simply present the variables in the form they are used in the model.

```
11600 PFRN.K=TABHL(PFRNT,TIME.K,0,170,5)
11601 PFRNT*=0.07302/0.07389/0.07477/0.07523/0.07568/0.07614/0.07660/0.0
X     7706/0.07752/0.07798/0.07844/0.07889/0.07935/0.07981/0.08027/0.081
X     18/0.08210/0.08301/0.08393/0.08485/0.08577/0.08668/0.08760/0.08852
X     /0.08945/0.09036/0.09128/0.09663/0.10229/0.10807/0.11419/0.11736/0
X     .12062/0.12470/0.12893

11602 SFRN=0.38999

11603 UFRN.K=TABHL(UFRNT,TIME.K,0,170,5)
11604 UFRNT*=0.53699/0.53612/0.53524/0.53478/0.53433/0.53387/0.53341/0.5
X     3295/0.53249/0.53203/0.53157/0.53112/0.53066/0.53020/0.52974/0.528
X     83/0.52791/0.52700/0.52608/0.52516/0.52424/0.52333/0.52241/0.52149
X     /0.52056/0.51965/0.51873/0.51338/0.50772/0.50194/0.49582/0.49265/0
X     .48940/0.48531/0.48108
```

```
11605 WCPIXN.K=TABHL(WCPIXT,TIME.K,0,170,5)
11606 WCPIXT*=0.73102/0.73277/0.73453/0.73544/0.73635/0.73727/0.73819/0.
X      73910/0.74002/0.74094/0.74186/0.74277/0.74369/0.74460/0.74552/0.74
X      735/0.74919/0.75101/0.75285/0.75468/0.75653/0.75835/0.76019/0.7620
X      2/0.76388/0.76570/0.76754/0.77824/0.78957/0.80113/0.81337/0.81970/
X      0.82621/0.83438/0.84285


NOTE  2) VARIABLES CONCERNING INDUSTRIAL ACTIVITY

11607 PJRN.K=TABHL(PJRNT,TIME.K,0,170,5)
11608 PJRNT*=0.9746/0.9795/0.9618/0.9713/0.9657/0.9683/0.9715/0.9728/0.9
X      650/0.9795/0.9755/0.9617/0.9741/0.9756/0.9831/0.9883/0.9857/0.9802
X      /0.9658/0.9652/0.9534/0.9779/1.0155/0.9901/0.9683/0.9348/0.9060/0.
X      9416/0.9899/0.9899/1.0004/0.9854/0.9732/0.9754/0.9926


11609 SJRN.K=TABHL(SJRNT,TIME.K,0,170,5)
11610 SJRNT*=0.9768/0.9779/0.9601/0.9687/0.9633/0.9652/0.9684/0.9699/0.9
X      621/0.9761/0.9721/0.9595/0.9719/0.9721/0.9794/0.9848/0.9822/0.9759
X      /0.9614/0.9614/0.9497/0.9718/1.0088/0.9874/0.9658/0.9316/0.9029/0.
X      9335/0.9819/0.9809/0.9921/0.9777/0.9659/0.9685/0.9862


11611 UJRN.K=TABHL(UJRNT,TIME.K,0,170,5)
11612 UJRNT*=0.9753/0.9792/0.9607/0.9700/0.9642/0.9667/0.9698/0.9709/0.9
X      630/0.9774/0.9733/0.9594/0.9716/0.9731/0.9804/0.9853/0.9825/0.9767
X      /0.9622/0.9613/0.9495/0.9736/1.0109/0.9854/0.9636/0.9300/0.9012/0.
X      9338/0.9827/0.9796/0.9909/0.9751/0.9631/0.9643/0.9818


11613 TJRN.K=TABHL(TJRNT,TIME.K,0,170,5)
11614 TJRNT*=0.9758/0.9787/0.9605/0.9696/0.9640/0.9663/0.9694/0.9707/0.9
X      628/0.9771/0.9730/0.9596/0.9719/0.9729/0.9802/0.9853/0.9827/0.9767
X      /0.9622/0.9617/0.9499/0.9733/1.0105/0.9866/0.9649/0.9310/0.9023/0.
X      9344/0.9831/0.9812/0.9925/0.9774/0.9654/0.9673/0.9849


11615 UNPRTN.K=TABHL(UNPRTT,TIME.K,0,170,5)
11616 UNPRTT*=2.4199/2.1264/3.9484/3.0441/3.6042/3.3719/3.0615/2.9310/3.
X      7167/2.2937/2.6962/4.0378/2.8054/2.7101/1.9786/1.4652/1.7349/2.331
X      3/3.7811/3.8313/5.0084/2.6732/0.0000/1.3379/3.5142/6.8956/9.7722/6
X      .5576/1.6879/1.8757/0.7582/2.2636/3.4578/3.2677/1.5092


11617 NIFRN.K=TABHL(NIFRNT,TIME.K,0,170,5)
11618 NIFRNT*=0.50000/0.43966/0.39727/0.38447/0.37494/0.37985/0.38343/0.
X      38103/0.37917/0.38322/0.38627/0.36665/0.35150/0.36293/0.37172/0.36
X      927/0.36738/0.37404/0.37916/0.36842/0.36011/0.38665/0.40682/0.3582
X      3/0.32031/0.30437/0.29173/0.33123/0.36229/0.36018/0.35855/0.33757/
X      0.32107/0.28903/0.26352


11619 MIFRN.K=TABHL(MIFRNT,TIME.K,0,170,5)
11620 MIFRNT*=0.50000/0.48733/0.47401/0.44894/0.43112/0.41079/0.39741/0.
X      39147/0.38720/0.38104/0.37712/0.38674/0.39185/0.38165/0.37545/0.37
X      676/0.37749/0.37350/0.37125/0.37796/0.38180/0.36619/0.35747/0.3877
X      1/0.40500/0.40652/0.40601/0.37928/0.36357/0.36845/0.37173/0.38415/
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X       1/1.2382/1.2395/1.2266/1.2494/1.2594/1.2170/1.1777/1.1931/1.2212/1
X       .2465/1.2634/1.2687/1.2784/1.2928/1.3108/1.3116/1.2956

11637 UFOCRN.K=TABHL(UFOCRT,TIME.K,0,170,5)
11638 UFOCRT*=0.00000/0.00965/0.03982/0.06119/0.08427/0.08720/0.08445/.0
X       9197/0.10160/0.10051/0.10530/0.15772/0.18470/0.18332/0.17822/0.158
X       20/0.14580/0.13096/0.12528/0.13163/0.14396/0.13186/0.12206/0.14995
X       /0.17397/0.16505/0.14715/0.13327/0.11856/0.11093/0.09698/0.07672/0
X       .05186/0.04540/0.04059

11639 HCHFRN.K=TABHL(HCHFRT,TIME.K,0,170,5)
11640 HCHFRT*=0.07424/0.07371/0.07338/0.07302/0.07256/0.07216/0.07198/0.
X       07194/0.07190/0.07188/0.07186/0.07197/0.07172/0.07141/0.07118/0.07
X       142/0.07174/0.07212/0.07253/0.07297/0.07342/0.07442/0.07537/0.0763
X       3/0.07727/0.07825/0.07904/0.08313/0.08643/0.09058/0.09393/0.09590/
X       0.09749/0.09379/0.09065

11641 MCHFRN.K=TABHL(MCHFRT,TIME.K,0,170,5)
11642 MCHFRT*=0.39653/0.39355/0.39128/0.38848/0.38500/0.38164/0.37935/0.
X       37791/0.37642/0.37445/0.37166/0.36480/0.35754/0.35550/0.35371/0.35
X       397/0.35428/0.35461/0.35487/0.35556/0.35613/0.35853/0.36010/0.3535
X       4/0.34828/0.34733/0.34660/0.34780/0.34904/0.34259/0.33799/0.33345/
X       0.32913/0.31829/0.30991

11643 LCHFRN.K=TABHL(LCHFRT,TIME.K,0,170,5)
11644 LCHFRT*=0.52923/0.50244/0.48017/0.46306/0.44769/0.43668/0.42818/0.
X       41783/0.40913/0.40230/0.39743/0.39174/0.38435/0.37879/0.37390/0.37
X       465/0.37491/0.37447/0.37389/0.36745/0.36189/0.36547/0.36892/0.3707
X       5/0.37182/0.37802/0.38306/0.38813/0.39255/0.40257/0.41026/0.42024/
X       0.42913/0.44063/0.44872

11645 UFHFRN.K=TABHL(UFHFRT,TIME.K,0,170,5)
11646 UFHFRT*=0.00000/0.03029/0.05516/0.07544/0.09476/0.10952/0.12049/0.
X       13233/0.14254/0.15137/0.15904/0.17148/0.18639/0.19430/0.20121/0.19
X       995/0.19906/0.19880/0.19871/0.20401/0.20855/0.20158/0.19561/0.1993
X       7/0.20263/0.19640/0.19130/0.18093/0.17197/0.16427/0.15781/0.15040/
X       0.14425/0.14728/0.15072

11647 HRN.K=TABHL(HRNT,TIME.K,0,170,5)
11648 HRNT*=1.1620/1.1559/1.1566/1.1541/1.1545/1.1386/1.1216/1.1153/1.11
X       28/1.0940/1.0907/1.1373/1.1488/1.1353/1.1192/1.0975/1.0844/1.0688/
X       1.0627/1.0626/1.0695/1.0665/1.0562/1.0903/1.1136/1.1135/1.1013/1.1
X       006/1.0892/1.0974/1.0882/1.0699/1.0431/1.0543/1.0457

11649 FHRN.K=TABHL(FHRNT,TIME.K,0,170,5)
11650 FHRNT*=1.1620/1.1920/1.2241/1.2483/1.2753/1.2787/1.2753/1.2854/1.2
X       977/1.2892/1.2970/1.3727/1.4119/1.4090/1.4011/1.3717/1.3539/1.334/
X       1.3262/1.3350/1.3514/1.3358/1.3131/1.3618/1.3965/1.3857/1.3619/1.3
X       437/1.3154/1.3131/1.2921/1.2593/1.2189/1.2364/1.2313

11651 HQLIXN.K=TABHL(HQLIXT,TIME.K,0,170,5)
11652 HQLIXT*=1.5450/1.5107/1.4829/1.4591/1.4353/1.4164/1.4028/1.3895/1.
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X      0.39119/0.40439/0.41074


11621 DIFRN.K=TABHL(DIFRNT,TIME.K,0,170,5)
11622 DIFRNT*=0.00000/0.07301/0.12872/0.16659/0.19394/0.20936/0.21916/0.
X      22750/0.23363/0.23575/0.23661/0.24660/0.25665/0.25542/0.25283/0.25
X      396/0.25513/0.25246/0.24960/0.25362/0.25809/0.24716/0.23570/0.2540
X      6/0.27469/0.28911/0.30226/0.28949/0.27413/0.27137/0.26971/0.27829/
X      0.28774/0.30658/0.32574


11623 IBRN.K=TABHL(IBRNT,TIME.K,0,170,5)
11624 IBRNT*=1.0250/1.0200/1.0162/1.0130/1.0104/1.0083/1.0066/1.0053/1.0
X      043/1.0034/1.0027/1.0023/1.0019/1.0015/1.0012/1.0010/1.0008/1.0007
X      /1.0005/1.0004/1.0004/1.0003/1.0002/1.0002/1.0002/1.0001/1.0001/1.
X      0001/1.0001/1.0001/1.0001/1.0000/1.0000/1.0000/1.0000


11625 UFIBFN.K=TABHL(UFIBFT,TIME.K,0,170,5)
11626 UFIBFT*=0.00000/0.00345/0.01430/0.03046/0.04939/0.06801/0.08582/0.
X      10322/0.11949/0.13333/0.14558/0.16191/0.17832/0.18827/0.19664/0.20
X      632/0.21523/0.22082/0.22532/0.23377/0.24221/0.22229/0.20212/0.2020
X      1/0.20491/0.20687/0.21081/0.19090/0.16997/0.15512/0.14107/0.12814/
X      0.11738/0.11228/0.11034


11627 ICPIXN.K=TABHL(ICPIXT,TIME.K,0,170,5)
11628 ICPIXT*=1.5000/1.3667/1.2685/1.2179/1.1810/1.1705/1.1643/1.1535/1.
X      1455/1.1475/1.1497/1.1200/1.0949/1.1075/1.1189/1.1153/1.1122/1.121
X      6/1.1296/1.1148/1.1020/1.1395/1.1711/1.1042/1.0456/1.0153/0.9895/1
X      .0417/1.0882/1.0888/1.0888/1.0593/1.0333/0.9824/0.9378


NOTE  3) VARIABLES CONCERNING RESIDENTIAL ACTIVITY

11629 HCHRN.K=TABHL(HCHRNT,TIME.K,0,170,5)
11630 HCHRNT*=1.0000/1.0150/1.0334/1.0417/1.0553/1.0529/1.0456/1.0392/1.
X      0402/1.0222/1.0236/1.0723/1.0897/1.0912/1.0869/1.0766/1.0733/1.062
X      2/1.0619/1.0622/1.0725/1.0610/1.0447/1.0666/1.0805/1.0655/1.0453/1
X      .0364/1.0341/1.0353/1.0339/1.0142/0.9925/1.0683/1.1220


11631 MCHRN.K=TABHL(MCHRNT,TIME.K,0,170,5)
11632 MCHRNT*=1.0000/1.0033/1.0108/1.0151/1.0248/1.0197/1.0101/1.0012/0.
X      9997/0.9814/0.9841/1.0458/1.0743/1.0712/1.0627/1.0437/1.0325/1.014
X      9/1.0084/1.0020/1.0054/0.9908/0.9734/1.0146/1.0452/1.0361/1.0185/0
X      .9998/0.9762/0.9878/0.9813/0.9694/0.9506/0.9846/0.9927


11633 TLCHRN.K=TABHL(TLCHRT,TIME.K,0,170,5)
11634 TLCHRT*=1.3061/1.3657/1.4271/1.4765/1.5265/1.5424/1.5488/1.5849/1.
X      6172/1.6233/1.6390/1.7324/1.7861/1.7860/1.7810/1.7380/1.7113/1.688
X      6/1.6791/1.7114/1.7484/1.7302/1.6995/1.7537/1.7913/1.7731/1.7378/1
X      .7176/1.6790/1.6524/1.6072/1.5453/1.4761/1.4540/1.4182


11635 LCHRN.K=TABHL(LCHRNT,TIME.K,0,170,5)
11636 LCHRNT*=1.3061/1.3361/1.3022/1.2811/1.2540/1.2566/1.2682/1.2725/1.
X      2671/1.2749/1.2715/1.1882/1.1508/1.1527/1.1614/1.1876/1.2037/1.229
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X       0.39119/0.40439/0.41074

11621 DIFRN.K=TABHL(DIFRNT,TIME.K,0,170,5)
11622 DIFRNT*=0.00000/0.07301/0.12872/0.16659/0.19394/0.20936/0.21916/0.
X       22750/0.23363/0.23575/0.23661/0.24660/0.25665/0.25542/0.25283/0.25
X       396/0.25513/0.25246/0.24960/0.25362/0.25809/0.24716/0.23570/0.2540
X       6/0.27469/0.28911/0.30226/0.28949/0.27413/0.27137/0.26971/0.27829/
X       0.28774/0.30658/0.32574

11623 IBRN.K=TABHL(IBRNT,TIME.K,0,170,5)
11624 IBRNT*=1.0250/1.0200/1.0162/1.0130/1.0104/1.0083/1.0066/1.0053/1.0
X       043/1.0034/1.0027/1.0023/1.0019/1.0015/1.0012/1.0010/1.0008/1.0007
X       /1.0005/1.0004/1.0004/1.0003/1.0002/1.0002/1.0002/1.0001/1.0001/1.
X       0001/1.0001/1.0001/1.0001/1.0000/1.0000/1.0000/1.0000

11625 UFIBFN.K=TABHL(UFIBFT,TIME.K,0,170,5)
11626 UFIBFT*=0.00000/0.00345/0.01430/0.03046/0.04939/0.06801/0.08582/0.
X       10322/0.11949/0.13333/0.14558/0.16191/0.17832/0.18827/0.19664/0.20
X       632/0.21523/0.22082/0.22532/0.23377/0.24221/0.22229/0.20212/0.2020
X       1/0.20491/0.20687/0.21081/0.19090/0.16997/0.15512/0.14107/0.12814/
X       0.11738/0.11228/0.11034

11627 ICPIXN.K=TABHL(ICPIXT,TIME.K,0,170,5)
11628 ICPIXT*=1.5000/1.3667/1.2685/1.2179/1.1810/1.1705/1.1643/1.1535/1.
X       1455/1.1475/1.1497/1.1200/1.0949/1.1075/1.1189/1.1153/1.1122/1.121
X       6/1.1296/1.1148/1.1020/1.1395/1.1711/1.1042/1.0456/1.0153/0.9895/1
X       .0417/1.0882/1.0888/1.0888/1.0593/1.0333/0.9824/0.9378

NOTE    3) VARIABLES CONCERNING RESIDENTIAL ACTIVITY

11629 HCHRN.K=TABHL(HCHRNT,TIME.K,0,170,5)
11630 HCHRNT*=1.0000/1.0150/1.0334/1.0417/1.0553/1.0529/1.0456/1.0392/1.
X       0402/1.0222/1.0236/1.0723/1.0897/1.0912/1.0869/1.0766/1.0733/1.062
X       2/1.0619/1.0622/1.0725/1.0610/1.0447/1.0666/1.0805/1.0655/1.0453/1
X       .0364/1.0341/1.0353/1.0339/1.0142/0.9925/1.0683/1.1220

11631 MCHRN.K=TABHL(MCHRNT,TIME.K,0,170,5)
11632 MCHRNT*=1.0000/1.0033/1.0108/1.0151/1.0248/1.0197/1.0101/1.0012/0.
X       9997/0.9814/0.9841/1.0458/1.0743/1.0712/1.0627/1.0437/1.0325/1.014
X       9/1.0084/1.0020/1.0054/0.9908/0.9734/1.0146/1.0452/1.0361/1.0185/0
X       .9998/0.9762/0.9878/0.9813/0.9694/0.9506/0.9846/0.9927

11633 TLCHRN.K=TABHL(TLCHRT,TIME.K,0,170,5)
11634 TLCHRT*=1.3061/1.3657/1.4271/1.4765/1.5265/1.5424/1.5488/1.5849/1.
X       6172/1.6233/1.6390/1.7324/1.7861/1.7860/1.7810/1.7380/1.7113/1.688
X       6/1.6791/1.7114/1.7484/1.7302/1.6995/1.7537/1.7913/1.7731/1.7378/1
X       .7176/1.6790/1.6524/1.6072/1.5453/1.4761/1.4540/1.4182

11635 LCHRN.K=TABHL(LCHRNT,TIME.K,0,170,5)
11636 LCHRNT*=1.3061/1.3361/1.3022/1.2811/1.2540/1.2566/1.2682/1.2725/1.
X       2671/1.2749/1.2715/1.1882/1.1508/1.1527/1.1614/1.1876/1.2037/1.229
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X      1/1.2382/1.2395/1.2266/1.2494/1.2594/1.2170/1.1777/1.1931/1.2212/1
X      .2465/1.2634/1.2687/1.2784/1.2928/1.3108/1.3116/1.2956


11637 UFOCRN.K=TABHL(UFOCRT,TIME.K,0,170,5)
11638 UFOCRT*=0.00000/0.00965/0.03982/0.06119/0.08427/0.08720/0.08445/.0
X      9197/0.10160/0.10051/0.10530/0.15772/0.18470/0.18332/0.17822/0.158
X      20/0.14580/0.13096/0.12528/0.13163/0.14396/0.13186/0.12206/0.14995
X      /0.17397/0.16505/0.14715/0.13327/0.11856/0.11093/0.09698/0.07672/0
X      .05186/0.04540/0.04059


11639 HCHFRN.K=TABHL(HCHFRT,TIME.K,0,170,5)
11640 HCHFRT*=0.07424/0.07371/0.07338/0.07302/0.07256/0.07216/0.07198/0.
X      07194/0.07190/0.07188/0.07186/0.07197/0.07172/0.07141/0.07118/0.07
X      142/0.07174/0.07212/0.07253/0.07297/0.07342/0.07442/0.07537/0.0763
X      3/0.07727/0.07825/0.07904/0.08313/0.08643/0.09058/0.09393/0.09590/
X      0.09749/0.09379/0.09065


11641 MCHFRN.K=TABHL(MCHFRT,TIME.K,0,170,5)
11642 MCHFRT*=0.39653/0.39355/0.39128/0.38848/0.38500/0.38164/0.37935/0.
X      37791/0.37642/0.37445/0.37166/0.36480/0.35754/0.35550/0.35371/0.35
X      397/0.35428/0.35461/0.35487/0.35556/0.35613/0.35853/0.36010/0.3535
X      4/0.34828/0.34733/0.34660/0.34780/0.34904/0.34259/0.33799/0.33345/
X      0.32913/0.31829/0.30991


11643 LCHFRN.K=TABHL(LCHFRT,TIME.K,0,170,5)
11644 LCHFRT*=0.52923/0.50244/0.48017/0.46306/0.44769/0.43668/0.42818/0.
X      41783/0.40913/0.40230/0.39743/0.39174/0.38435/0.37879/0.37390/0.37
X      465/0.37491/0.37447/0.37389/0.36745/0.36189/0.36547/0.36892/0.3707
X      5/0.37182/0.37802/0.38306/0.38813/0.39255/0.40257/0.41026/0.42024/
X      0.42913/0.44063/0.44872


11645 UFHFRN.K=TABHL(UFHFRT,TIME.K,0,170,5)
11646 UFHFRT*=0.00000/0.03029/0.05516/0.07544/0.09476/0.10952/0.12049/0.
X      13233/0.14254/0.15137/0.15904/0.17148/0.18639/0.19430/0.20121/0.19
X      995/0.19906/0.19880/0.19871/0.20401/0.20855/0.20158/0.19561/0.1993
X      7/0.20263/0.19640/0.19130/0.18093/0.17197/0.16427/0.15781/0.15040/
X      0.14425/0.14728/0.15072


11647 HRN.K=TABHL(HRNT,TIME.K,0,170,5)
11648 HRNT*=1.1620/1.1559/1.1566/1.1541/1.1545/1.1386/1.1216/1.1153/1.11
X      28/1.0940/1.0907/1.1373/1.1488/1.1353/1.1192/1.0975/1.0844/1.0688/
X      1.0627/1.0626/1.0695/1.0665/1.0562/1.0903/1.1136/1.1135/1.1013/1.1
X      006/1.0892/1.0974/1.0882/1.0699/1.0431/1.0543/1.0457


11649 FHRN.K=TABHL(FHRNT,TIME.K,0,170,5)
11650 FHRNT*=1.1620/1.1920/1.2241/1.2483/1.2753/1.2787/1.2753/1.2854/1.2
X      977/1.2892/1.2970/1.3727/1.4119/1.4090/1.4011/1.3717/1.3539/1.334/
X      1.3262/1.3350/1.3514/1.3358/1.3131/1.3618/1.3965/1.3857/1.3619/1.3
X      437/1.3154/1.3131/1.2921/1.2593/1.2189/1.2364/1.2313


11651 HQLIXN.K=TABHL(HQLIXT,TIME.K,0,170,5)
11652 HQLIXT*=1.5450/1.5107/1.4829/1.4591/1.4353/1.4164/1.4028/1.3895/1.
```

```
X       3777/1.3668/1.3564/1.3373/1.3146/1.3040/1.2949/1.2969/1.2987/1.300
X       0/1.3012/1.2975/1.2944/1.3058/1.3152/1.3068/1.3002/1.3074/1.3134/1
X       .3331/1.3499/1.3595/1.3680/1.3749/1.3799/1.3586/1.3405

11653 RIARN.K=TABHL(RIARNT,TIME.K,0,170,5)
11654 RIARNT*=4.4729/4.2931/4.2129/4.1370/4.1149/4.0932/4.0926/4.0504/4.
X       0246/3.9703/3.9217/3.8817/3.8656/3.8474/3.8270/3.9390/4.0547/4.102
X       1/4.1431/4.1465/4.1622/4.0748/3.9565/4.0667/4.2084/4.5461/4.9245/4
X       .9414/4.9025/5.0545/5.2009/5.5369/5.9062/6.0955/6.3207

NOTE    4) VARIABLES CONCERNING PUBLIC EXPENDITURE

11655 PCEXN.K=TABHL(PCEXNT,TIME.K,0,170,5)
11656 PCEXNT*=1.021/1.163/1.255/1.312/1.340/1.394/1.448/1.532/1.601/1.75
X       0/1.870/1.986/2.157/2.210/2.276/2.551/2.794/3.098/3.365/4.200/5.00
X       9/5.940/7.005/12.002/17.132/16.893/16.720/19.633/23.044/26.169/29.
X       796/38.090/46.467/43.521/40.917

11657 PCRTVN.K=TABHL(PCRTVT,TIME.K,0,170,5)
11658 PCRTVT*=10.133/11.256/11.864/12.158/12.170/12.340/12.491/12.546/12
X       .482/12.695/12.685/12.853/13.348/13.239/13.209/13.008/12.706/12.50
X       1/12.205/12.443/12.542/12.774/13.203/13.430/13.633/13.766/13.961/1
X       4.204/14.707/14.816/15.159/15.137/15.149/15.516/16.093
```

8.12 CONTROL SECTOR

The model as presented so far, includes several control programs which may be taken to represent externally generated influences on the urban system. Those control programs may therefore be used for testing the effect of various externally supported efforts on the development of a given city.

The following set of equations describe the control programs used in the model.

```
*12000 UTRPG.K=(AUH.K)(UTR)(CLIP(0,1,ACT1,TIME.K))
 12001 STRPG.K=(ASH.K)(STR)(CLIP(0,1,ACT2,TIME.K))
 12002 NICRPG.K=(TIU.K)(ICRR.K)(CLIP(0,1,ACT3,TIME.K))
 12003 IBCNPG.K=(TIU.K)(IBCNR)(CLIP(0,1,ACT4,TIME.K))
*12004 LCHCPG.K=(HUOCLI.K)(LCHCR)(CLIP(0,1,ACT5,TIME.K))
 12005 MCHCPG.K=(HUOCMI.K)(MCHCR)(CLIP(0,1,ACT6,TIME.K))
 12006 HCHCPG.K=(HUOCHI.K)(HCHCR)(CLIP(0,1,ACT7,TIME.K))
 12007 UHCLPG.K=(UFHU.K)(UFHCLR)(CLIP(0,1,ACT8,TIME.K))
 12008 IBCLPG.K=(UFIB.K)(IBCLR)(CLIP(0,1,ACT9,TIME.K))
 12009 FNASPG.K=(TRTV.K)(FNASR.K)(CLIP(0,1,ACT10,TIME.K))

 12010 ACT1=200
 12011 ACT2=200
 12012 ACT3=200
 12013 ACT4=200
 12014 ACT5=200
 12015 ACT6=200
 12016 ACT7=200
 12017 ACT8=200
 12018 ACT9=200
 12019 ACT10=200

 12020 UTR=0
 12021 STR=0
 12022 ICRR=0
 12023 IBCNR=0
 12024 LCHCR=0

 12025 MCHCR=0
 12026 HCHCR=0
 12027 UFHCLR=0
 12028 IBCLR=0
 12029 FNASR=0
```

Equation 12000 describes the program simulating the training of unskilled employees (or Unskilled Training Program). The training rate expresses the number of Unskilled Heads which are trained during a given period as a function of the total number of Unskilled Heads at the beginning of the period. The CLIP function allows the program to be initiated at any point during the simulation run. Its value remains zero until TIME.K reaches the value set for ACT1 and then it becomes one thus activating the training program. Equations 12001-12009 describe in a similar way the rest of the control programs used in the model. The remaining equations of this sector define the activation times and the control rates for the various programs. In the present case no control programs are active; hence all activation times have been set to 200 (i.e. outside the 170-year period covered by the model) and all control rates have been set to zero.

All the programs presented above may be used either for impact-analysis or for planning purposes. In the former case one external influence is usually generated at a time and its effect on a specific activity or on the overall development of the city is assessed. In the case of planning however a more comprehensive approach is generally followed; more than one external influences are activated at the same time, in an attempt to cover a wider spectrum of urban activities, and their overall influence on the development of the city is examined. The control programs as presented so far can be activated only externally and for a pre-defined period of time. In the case of a planning application however, it may be required that certain programs can also be activated endogenously as a result of changes in the level of selected variables. This can be easily achieved if TIME.K is substituted by the variable which is chosen to control the activation and ACT is taken to represent its activation level. In the case of Low-Cost Housing Construction Program (eq. 12004) for example, if TIME.K is substituted by UFOCR.K (Unfit Housing Occupation Ratio) – which expresses the fraction of people living in unfit houses – and ACT1 is taken to represent the value of this fraction over which immediate action is required then the program will be activated every time UFOCR.K reaches this value. The remaining programs may also be modified in a similar way.

A further modification concerns the actual process of activation. All programs presented so far, whether endogenously or exogenously activated, they move from inactivity to full action in a single step. In certain cases however, it may be preferable to introduce a gradual transition. This can be easily achieved by substituting the fixed control rate by a variable. In the case of Low-Cost Housing Construction Program, for example, the fixed Low-Cost Housing Construction Rate (LCHCR) may be substituted by a variable, say LCHCR.K, depending on the value of UFOCR.K. In this way the fraction of population living in unfit houses determines the rate of Low-Cost Housing Construction. A similar modification may also be applied to the remaining programs.

I have so far presented several control programs which may be used to test the effect of various urban policies on the development of a given city. In the remaining part of this section I shall discuss constraints on city development. For the purposes of the model the performance of a given city is measured in terms of its Basic Image (i.e. the higher the Basic Image the more attractive the city) and several constraints heve been introduced concerning the availability of capital and manpower within the city. At this point I shall present a different type of constraints, namely constraints upon the interaction between the given city and its surrounding region. Every city is an open system which influences and it is also influenced by its surrounding environment. The influence of the city on its environment may only be ignored if we consider the rest of the country as "limitless" or as having infinite capacity of supplying and absorbing jobs, population and capital. Such an assumption, however, is not only false but it may also prove misleading. If the sole objective of every growing city is to speed up its growth irrespective of any potential adverse effects on the rest of the country then the surrounding region will soon shrink. In the words of G. Ingram[1] any urban model assuming an environment of infinite capacity may in effect be suggesting "that to see the parade better, one should stand on one's tiptoes. If everyone in the crowd does this no one can see better but all are less comfortable". Therefore a more careful approach to the interaction of a city with the rest of the country is required, especially if the model is to be used for planning purposes. A direct and explicit modelling of this interaction is extremely difficult since it essentially requires the analysis of industrial and population movements between the given and every city. Hence an indirect modelling approach must be followed. Such an approach is described below.

The main inter-city movements examined in the presented model concern new industrial units and professionally qualified employees. Therefore the surrounding environment of a given city may be considered as consisting of finite pools containing those entities.
I shall be referring to those pools as the "national pools". Obviously if evry attractive city draws excessively upon the contents of each pool without any obligation for their replacement they will soon dry up. Consequently, the planners responsible for the development of a city must take into account not only the state of the city itself but also the state of the "national pools". In theory this may be done in two ways:

(i) Restrict the flows of industry and population into an overgrown city thus conserving the contents of the "national pools".

(ii) Let the flows unrestricted but charge the cities which over-benefit from them towards the cost of replacement of the pools' contents.

In order to incorporate those ideas into the proposed model two new variables must be introduced. The first RCIU(Replacement Cost for Industrial Units) expresses the cost of replacement charged for excessive withdrawals, from the national industrial pools. It must be a function of three already defined variables: Total Industrial Units (TIU), Relative Industrial Composition Index (RICPIX) and Basic Image (BI). Higher than the normal Industrial Composition Index (or in other words a high proportion of new industries in the city's industrial stock) results in a "bill" for replacement costs. The charges towards the cost of replacement should be increasing with the value of the city's Basic Image. On the contrary, lower than normal Industrial Composition Index generates a negative replacement cost indicating the need for exogenous assistance. The second variable, RCQLE (Replacement Cost for Qualified Employees) expresses the cost of replacement charged for excessive withdrawals from the national workforce pools. It must be a function of three already defined variables – Total Economically Active (TA), Relative Workforce Composition Index (RWCPIX) and Basic Image (BI) – and it operates in the way discussed above.

The two variables RCIU, RCQLE can be used for modelling the city-environment interaction. If the first method of control is chosen this may be introduced into the model by considering the restrictions on industrial and population movement as increasing with the respective replacements costs. If the second method is chosen this may be introduced into the model by subtracting from the city revenue net payments increasing with the replacement costs. The choice of method and the severity of restrictions (or level of net payments) depend on the socio-political climate of the country under study and especially on the relative weights attached to the concepts of equity and economic efficiency respectively. A few alternative approaches are outlined in Figure 8.34.

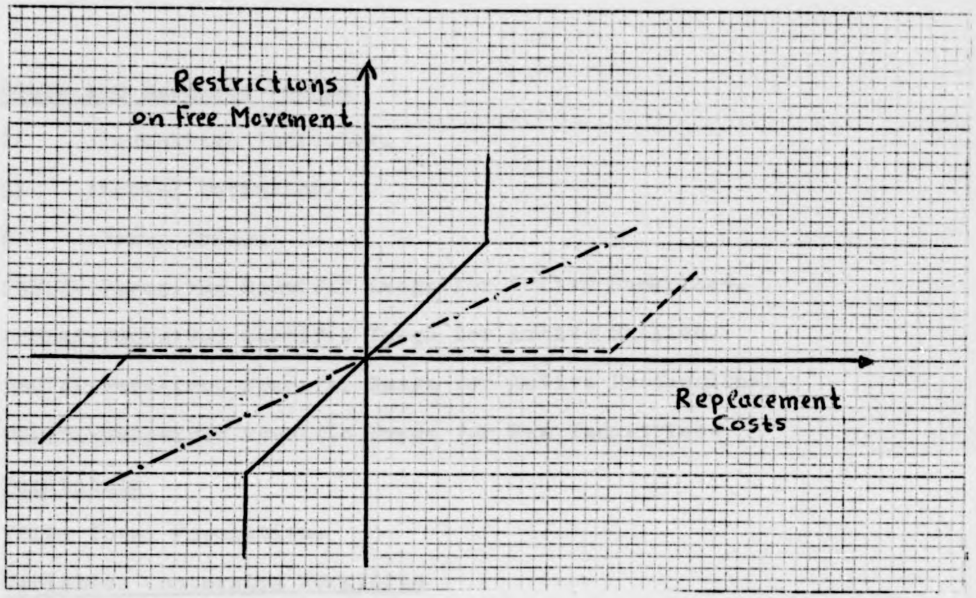

Figure 8.34

8.13 OUTPUT OF THE MODEL

I have so far presented a model which may be used to simulate the development of an urban system. The only requirements for the application of the model to a given city are:

(i) Knowledge of the initial state of the city's development or in other words the provision of initial values for all the level equations.

(ii) Provision of all variables expressing local trends.

(iii) Definition of the length of the simulation period.

The value of every variable generated in the model may be obtained as an output either printed or plotted. For the purposes of the model a set of output variables have been defined which are considered to express the state of a city's development at a given time. This set is referred to as the "Description of the City" and contains the following variables;

<u>Basic and Specific Images</u>

II :Industrial Indicator.

SI :Social Indicator.

BI :Basic Image.

PSPIAU:Perceived Specific Image for Active Unskilled.

PSPIAS:Perceived Specific Image for Active Skilled.

PSPIAP:Perceived Specific Image for Active Professional.

PSPINI:Perceived Specific Image for New Industries.

<u>Population</u>

TOTP: Total Population.

<u>Variables Concerning Workforce</u>

1.<u>Levels</u>

AUH: Active Unskilled Heads.

ASH: Active Skilled Heads.

APH: Active Professional Heads.

RH : Retired Heads.

2. <u>Rates</u>

RUFR : Relative Unskilled Fraction.

RSFR : Relative Skilled Fraction.

RPFR : Relative Professional Fraction.

RWCPIX: Relative Workforce Composition Index.

<u>Variables Concerning Industrial Activity</u>

1.<u>Levels</u>

NIU : New Industrial Units.

MIU : Mature Industrial Units.

DIU : Declining Industrial Units.

TIU : Total Industrial Units.

TJ : Total Jobs.

FIB : Fit Industrial Buildings.

UFIB: Unfit Industrial Buildings.

2. Rates

RNIFR : Relative New Industries Fraction.

RMIFR : Relative Mature Industries Fraction.

RDIFR : Relative Declining Industries Fraction.

RICPIX: Relative Industrial Composition Index.

RTJR : Relative Total Job Ratio.

RUFIBF: Relative Unfit Industrial Buildings Fraction.

Variables Concerning Residential Activity

1. Levels

HCHU: High-Cost Housing Units.

MCHU: Medium-Cost Housing Units.

LCHU: Low-Cost Housing Units.

FHU : Fit Housing Units.

UFHU: Unfit Housing Units.

THU : Total Housing Units.

2. Rates

RHCHFR: Relative High-Cost Housing Fraction.

RMCHFR: Relative Medium-Cost Housing Fraction.

RLCHFR: Relative Low-Cost Housing Fraction.

RUFHFR: Relative Unfit Housing Fraction.

8.4. MODIFICATIONS FOR THE CASE OF A CITY FUNCTIONING WITHIN ITS COMMUTER REGION

The Urban Entities Generation Submodel although constructed for the case of cities where all economically active employees work and live within the politically fixed boundaries it may also be used for the case of cities functioning within a wider commuting region. No essential changes are required. However one could slightly modify any relationships involving factors whose importance declines in the latter case. Such factors have been presented in Chapter 7 and include job availability, job prospects, labour availability and labour quality.

REFERENCE

1. INGRAM.G.K. Book Review on Urban Dynamics by J.W. FORRESTER, Journal of the American Institute of Planners, May, 1970, pp. 206-208.

Chapter 9

Urban-Entities Location Submodel

9.1 ALTERNATIVE APPROACHES OF MODELLING SPATIAL DISTRIBUTION

In designing the model which has been presented in the last five chapters my emphasis was placed on the analysis of the mechanisms governing the attraction power and consequently the overall development of an industrial city. Although land availability and land use were among the factors considered to influence the growth of a city, the actual distribution of urban entities over the city area has not been included in the working model for reasons explained in Chapters 2 and 4. Location, however, is an important subject in its own right and it will be interesting to see how the proposed model may be extended so as to cover it. This may be generally done in two ways. The first, consistent with my assumption of no significant interdependence between locational patterns and long-term development of the city, is quite straight forward. The stocks of urban entities which are calculated at each simulation run are the inputs of a location submodel which, in turn, distributes them over the city area. The submodel is simply added to the existing model and the only modification required is the enlargement of the "Description of the City" so as to include variables related to the location of urban entities as well. Those variables although they may influence subsequent locational patterns, as we shall see in due course, do not affect at all the Basic and Specific Images of the city (Figure 9.1).

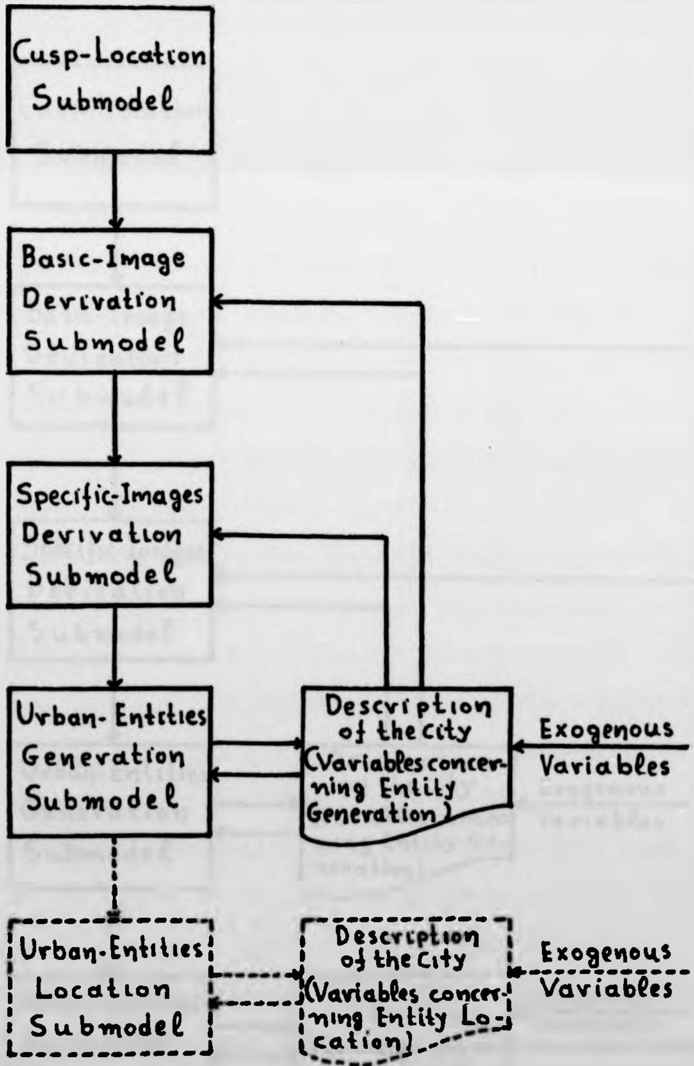

Figure 9.1 First approach of modelling spatial distribution

If the modeller, on the other hand, feels that the spatial pattern of urban activities significantly affects the long-term development of the city then the dependence of the Basic and Specific Image of the city on variables related to the spatial distribution of urban entities, must be modelled explicitly (Figure 9.2).

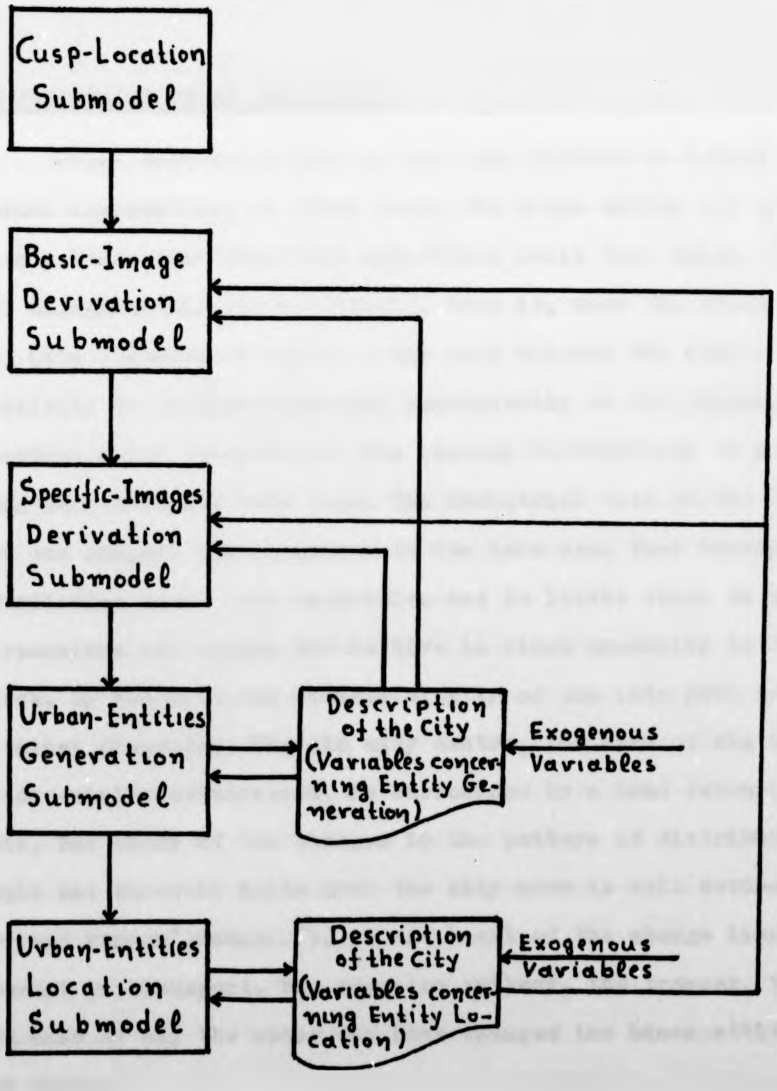

Figure 9.2 Second approach of modelling spatial distribution

In either case, a location submodel must be constructed and I shall now go on to discuss its structure. What follows in this chapter, however, is only an outline of how the proposed model can be extended and it must be read in this light. A brief analysis of location process is presented together with suggestions for its modelling but the coverage of the subject is by no means complete.

9.2 THE PROCESS OF URBAN DISPERSION

Urban activities have so far been treated at a high level of spatial aggregation; in other words the urban system was considered as a large zone where all activities could take place. When spatial disaggregation is introduced, that is, when the system is divided into a number of zones, a new need arises; the need to relate each activity to certain zones and consequently to the physical infrastructure which contains it. The spatial distribution of activities has been changing over time. The industrial city in the 19th century was compact and intensive in its land use. Poor transportation facilities meant that industries had to locate close to natural resources and people had to live in close proximity to their workplace. By contrast, the industrial city of the late 20th century is rather dispersed. The old city centre, the area of the initial industrial concentration, is surrounded by a land devouring suburbia. The story of the changes in the pattern of distribution of people and economic units over the city area is well documented (Hoover and Vernon[1], Manners[2]). At the heart of the change lies the improvement in transport. The commuter railway, the tramcar, the bus and most of all the motor car have changed the human attitude towards space.

The first to move out of the compact centre of the 19th century industrial city were the middle classes. Their movement was inspired by the need for better surroundings and healthier environment and it was facilitated by the new means of transport which reduced the importance of the access to work factor. While the standard of living of those who could move improved, the old central courts declined and those who left behind degenerated into slum dwellers. This initial class separation became a permanent feature of the industrial city. As the blighted central area kept expanding the better-off were pushed further out. For some families life became a succession of new houses while for others a succession of third and fourth hand-ones.

Retail trade followed the better-off into the suburbs. The need for proximity to a large and affluent market, together with the availability of cheap land and ample space were the main factors behind the outward movement of the retail activity. Dispersion of retailing had naturally a considerable effect on the location of warehouses and indeed many wholesalers were very quick to follow the retailing outlets into the suburbs.

Manufacturing industry was the next group to be released from the ties of the central city. Improvements in communications, and especially the exploitation of road transports, lessened the need for an industry to be close to natural resources and rail termini and also reduced the cost and time of moving people and goods. Consequently the central areas lost their unique features. In addition shortage of space, at a time when the new production methods required increasingly large land plots, proved a further handicap. For many manufacturers the positive attractions of the suburbs, such as ample space and lower rates, were overwhelming and an outward movement begun. The start of this outward movement, however, coincided —at least in Britain and in most West European countries— with a period of increasing Government intervention in the process of industrial location. Hence, the pattern of distribution of the 20th century industries is to a large extent the outcome of deliberate zoning regulations. Futhermore the location of war industries, which was mainly influenced by strategic reasons, has played, in many cases, a decisive role in the spatial distribution of post-war activity. Summarising,I could say that the overall trend in the manufacturing employment has been in the direction of a less centralised pattern.

The only economic activity still to retain strong ties with the central city is office employment. Although economic factors encourage outward movement and improvements in communication methods have made suburban locations a viable alternative the preference for central locations remains. The main advantages of such locations for office employers include geographical proximity of similar and related activities and the prestige offered by a central city site.

The process of spatial distribution for the various urban activities discussed so far indicates a clear switch to decentralisation. This has resulted to a decline in the number of jobs in the central area, a certain amount of "reverse-commuting" for many city-centre dwellers and an increased pressure for low-cost accommodation close to the surbanised employment concentrations. Furthermore the ever-increasing commuting distance to the city centre for those living in the farthest and outwardly moving residential zones has brought the access factor back to the picture as constraint and possible limit to spead. This has reflected to a slow "return--flow" to the city centre of a small minority of high income people in executive and professional jobs which seemrather firmly rooted to the city centre. However, the extremely high rents and land values in the central areas make the prospects of a substantial increase in the "return-flow" highly unlikely.

9.3 INTERNAL STRUCTURE OF THE CITY

Having described the transformation of the compact city of the 19th century into the dispersed urban area of the 20th century, I shall now concentrate on the internal structure of the latter. Land use patterns result from a multitude of decisions made by individuals about location; most of those decisions are regulated by the economic process operating in society. The operation of the forces related to spatial distribution can be summarised as follows (Garner[3]). Each activity may derive utility from the use of every site in the urban area; the utility is measured by the rent it is willing to pay for using the site. Competition between activities results, eventually, in the occupation of each site by the activity which is willing and able to pay the highest price. The rent paid for the use of a site depends on several factors the most important of which is its location relative to other uses. Viewed in this light rent may be considered a function of variations in accessibility. Accessibility, however, is perceived differently by the various activities as I have mentioned in the previous section. Manufacturing activity is attracted by accessibility to raw materials, suitable single land plots of sufficient size and transport facilities. Commercial activity on the other hand requires close proximity to large and affluent markets. For office employment, easy access to complementary uses appears to be the crucial factor. Finally, residential activity is not only influenced by proximity to work places, shopping facilities and social amenities but also by factors expressing environmental quality. The multitude of factors controlling the location of urban activities makethe internal structure of any city unique in its detail; however a degree of order underlying the land use patterns of individual cities seems to exist. The specific nature of this order is still a matter for debate but nevertheless several patterns have been identified and some of them are discussed below:

Pure Concentric Structure: This pattern occurs when land values and consequently accessibility decline with equal regularity in all directions from the city centre. Urban entities are then arranged in concentric zones about the centre. The concentric model was originally proposed by Burgess[4] and it was based mainly on his studies of the Chicago region. The five zones he identified are shown in Figure 9.3 .

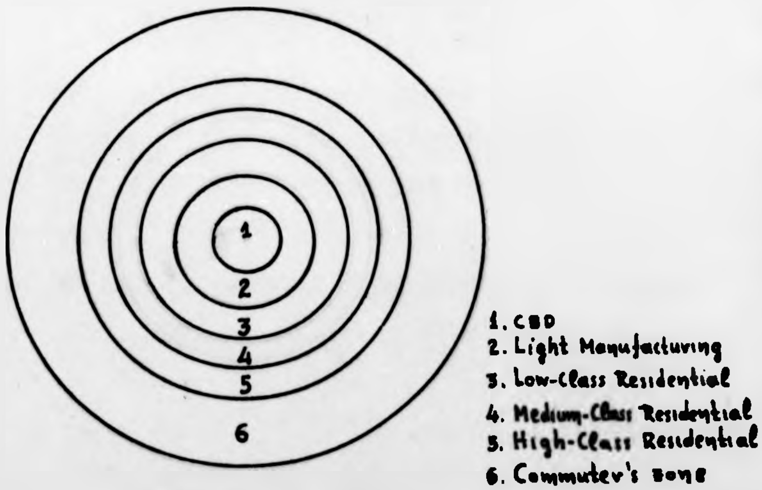

Figure 9.3

Pure Concentric Structure

Apart from Chicago, concentric patterns have been found in Philadelphia and Calgary, Canada as well as in many Dutch cities. In general, however, concentric land use patterns will result only if there is a large number of closely spaced radial routes and neither historical nor geographical differences have favoured development along one axis in preference to others.

Sectoral Structure: Fewer and widely spaced radial routes distort the concentric pattern. Differences in intra-radial accessibility and the tedency of similar uses to concentrate along a particular route give rise to arrangements of land uses into sectors.

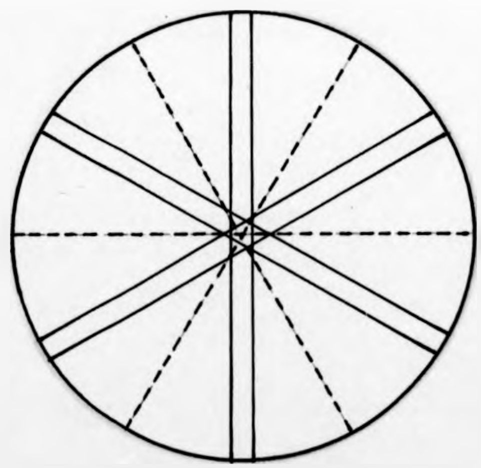

Figure 9.4

Pure Sectoral Structure

In the sectoral pattern shown in Figure 9.4 direction rather than distance is the primary influence. More often however, a modified sectoral pattern occurs as a result of locational decisions based on both direction and distance. Such a model was originally introduced by Hoyt[5] who suggested a pattern of concentric arrangements with a sectoral framework (Figure 9.5).

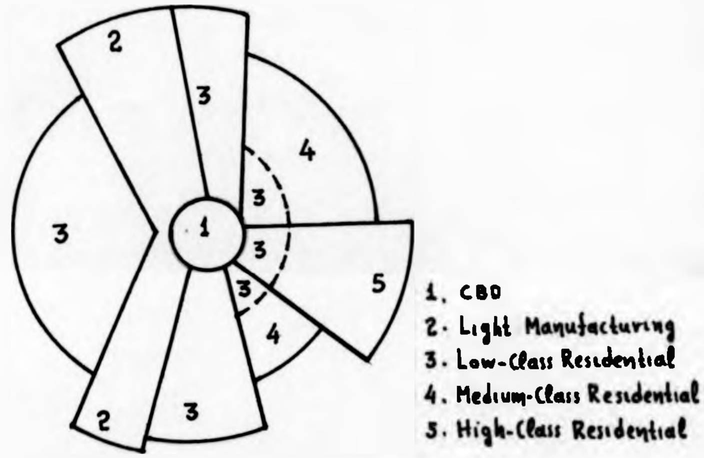

Figure 9.5

Modified Sectoral Structure

Sectoral arrangements have been identified in cities such as Chicago, Belfast as well as areas along the nothern shore of lake of Michigan.

Star-Structure: Few and widely spaced radial routes together with the incorporation of open land between them give rise to a structure which is star-shaped in the centre and linear in the periphery. The city-core remains the dominant area but it is now surrounded by secondary centres distributed along the radials. Land uses on the main axes, however, are usually arranged in concentric zones(Figure 9.6).

The star-shaped pattern may be considered as a rationalised version of city development in the pre-car era but it is also the form that many cities (i.e. Copenhagen) have chosen as the pattern for their future growth (Lynch[6]).

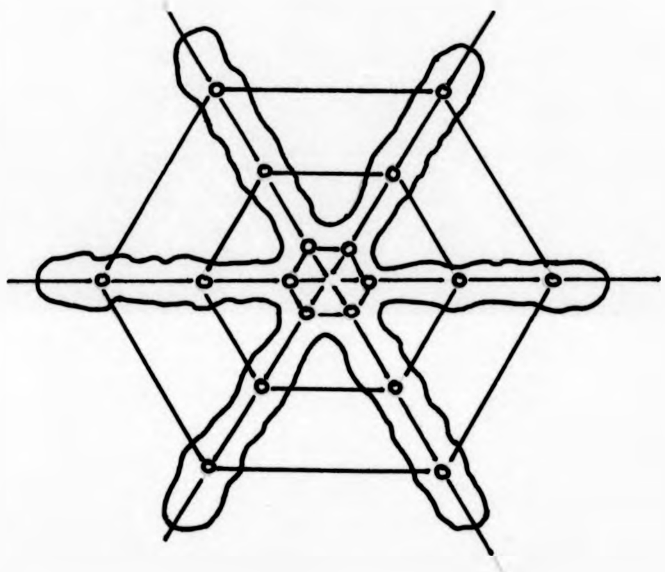

Figure 9.6

Star Structure

Multiple-Nucleii Structure: All three structures described so far were referring to a city growing around a single centre. By contrast this fourth approach considers several discrete centres whose number and location depends on the size and historical development of the given urban area. The multiple-nucleii structure was originally proposed by Harris and Ullman[7] who, in the case of American cities, identified the five districts shown in Figure 9.7.

Many German and Dutch regions have also been developed along this pattern, the typical example being the Ruhr area.

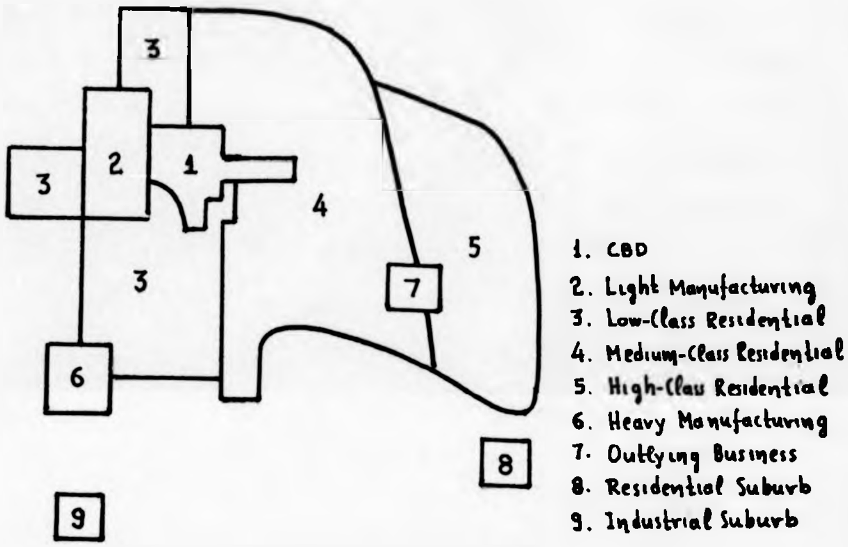

Figure 9.7

Multiple-Nucleii Structure

Concluding I may add that the four patterns presented in this section are not mutually exclusive; on the contrary, elements of all four structures may be expected in cities especially when they have combined with one another to form large conurbations.

9.4 OUTLINE OF A LOCATION SUBMODEL

I have so far discussed the process of urban dispersion and identified the main factors controlling the internal structure of a city. My objective in this section is to suggest ways of modelling the process of activity location. Models of urban structure are basically of two kinds:(i) partial, covering a limited set of specified urban activities and (ii) comprehensive, dealing with the location of all urban activities within the urban area. The activity generation submodel presented in Chapter 8 covers two types of activity;industrial and residential. Therefore, the corresponding location submodel can only deal with the same activities. Furthermore, industrial activity has so far been treated generally and no explicit distinction has been made between manufacturing , commercial or other any type of employment. For the purposes of spatial distribution, however, it may be preferable to treat them differently. In such a case the generation submodel can be easily modified so as to generate various types of industrial activity separately.

The model presented in the last four chapters has been built around the concepts of Basic and Specific Image of a city. In the case of the location submodel, however, the concept of Basic Image is not applicable any more. Its use implicitly suggests that the prosperity of a city-zone depends on its ability to attract both industries and people. As we have seen already such a suggestion may only be true during the early stages of a country's industrialisation when the concepts of "city" and "city-zone" are almost identical. In later stages of development, activity separation is not only a natural consequence but also a desirable and sought-after situation. Unlike Basic Image the concept of Specific Image may be successfully applied in the case of activity location; indeed the distribution of people and industries over the city-zones may be based on the corresponding Specific Images of the various zones as perceived by them. The method proposed for modelling the distribution of industrial and residential activities is based on the concept of Specific Image and consists of the following steps:

Division of the city-area into zones.

Definition of the distributable entities.

Derivation of Specific Images for every zone.

Allocation of urban activities to city-zones.

Allocation of physical infrastructure to city-zones.

Let me now analyse briefly each of those steps.

Division of the city-area into zones: Several views on the subject of a city's internal structure have been discussed in section 9.3; the final choice depends on the particular city under consideration. Sometimes, however, difficulties in obtaining the required data restricts our choice and simpler patterns such as uniform grids or the existing political ward division may be used.

Definition of the distributable entities: The number and type of distributable entities depends on the activities covered by the model. In the present case industrial and residential activities are studied; hence the distributable entities are industrial units, population and also those expressing the corresponding physical infrastructure i.e. industrial buildings and housing units.

Derivation of Specific Images for every zone: Every zone is considered as venue for both industrial and residential activities; therefore two Specific Images, as perceived by industrial units and prospective residents respectively, must be generated for each zone. The main factors controlling the spatial distribution of industrial activity are, as identified in sections 9.2 and 9.3, proximity to markets and raw materials, availability of suitable land, proximity to transportation facilities and finally zoning regulations. The corresponding Specific Image must be a function of all those factors. If the model distinguishes between various types of industrial activity separate Specific Images must be generated for each type.

Similarly the Specific Image of a zone as perceived by the prospective residents must be considered as a function of the following factors:proximity to employment and shopping facilities, pleasant and healthy environment, availability of suitable housing. As in the case of the city as a whole the Specific Image will be calculated separately for each group of residents classified according to their income level.

Allocation of urban activities to city-zones: Let me start with the industrial activity. The allocation of industrial units to zones may be done on the basis of the corresponding Specific Images. In other words the number of industrial units in every zone may be given as a fraction of the total number of industrial units in the city proportional to the zone's Specific Image. Location in the zone of their first preference will not, generally, be possible for all industrial units for a variety of reasons. Hence the model should include an algorithm generating the allocation of industrial units, which have failed to satisfy their first choice, into zones of their second, third etc. preferences. Relocation of industrial activity may also be taken into account; indeed the number of industrial units seeking relocation may be considered as a function, among other variables, of the number of industrial units which have not satisfied their location preferences. Relocation of industrial units within the same city, however, is not a very common practice and it may be ignored in most cases.

The allocation of residential activity may be done in the same way . An algorithm for the allocation of prospective residents who could not find a house in the zone of their first choice must also be include. Finally, relocation may be also modelled along the lines indicated in the previous section. Unlike the case of industrial units the change of residential places is very common and its modelling is essential.

Allocation of physical infrastructure to city-zones: The activity generation submodel presented in Chapter 8, assumes that industrial buildings are normally constructed by the Private Sector only. Their allocation to city-zones may be done according to what I call an Industrial Building Construction Coefficient. Factors affecting such a coefficient for a given zone include availability and expected demand for industrial buildings, availability of suitable land and also its cost.

Contrary to the case of industrial buildings the model allows for housing construction by both Private and Public Sectors. Furthermore it assumes that the factors influencing housing construction in each case are not identical. Consequently it will be better to treat the distribution of housing units constructed by each of those sectors differently. The allocation of housing units constructed by the Private Sector to the various zones may be done on the basis of what I call a Private Housing Construction Multiplier. In other words every zone will include a fraction of the privately constructed houses proportional to its Housing Construction Multiplier. Factors affecting such a coefficient for a given zone, include housing availability and expected housing demand, land availability and cost. The same procedure may be followed in the case of housing units constructed by the Public Sector. The only difference is that the factors influencing the construction multiplier in this case may also include a measure of the number of families living in unfit houses as well as the level of expenditure on housing for that particular zone. As in the case of the city as a whole the construction multipliers will be calculated separately for each one of the three groups of housing units.

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Chapter 10

Potential of the Model for Prediction and Planning

As I have mentioned already in Chapter 2,models may be divided according to the purpose for which they are designed into descriptive, predictive, and planning. The model presented in the last five chapters may be classified as descriptive one in the sense that it was mainly concerned with the understanding of the mechanisms governing the growth or decline of a particular type of city, the industrial city. My main objective in this chapter is to assess its potential for prediction and planning. Since, however, a planning model is necessarily capable for prediction I shall concentrate in assessing the planning potential of the proposed model.

10.1 THE PLANNING PROCESS

Planning is a term applicable to a wide variety of activities. In the context of urban systems, planning is a deliberate attempt to regulate the process of urbanisation and to devise policies which may direct it towards desired goals. Today urban planning is a universally accepted practice and governments throughout the world are adopting urban growth strategies. Planning,however, has not always been a feature of the urbanisation process; on the contrary, as late as 1920 almost nobody wanted the Government to determine how the cities should grow. Reaction against the high level of degradation of urban environment during the 19th century and more generally, reaction against the human consequences of that period's underlying socio-economic ideology brought about a sequence of new socio-political forms favouring a public involvement in the running of the country's economy. In urban terms, this change of attitude meant a trend towards increasing public intervention, aiming to correct the social consequences of the 19th century urban explosion and also to control any further urbanisation. The diverse forms of public intervention the variety of goals which are sought after and socio-political differences from one society to another, combine to produce distinct planning-styles leading to divergent paths of urbanisation.

B. Berry[1] distinguishes four modes of planning:

Ameliorative, Problem-Solving

Allocative, Trend-Modifying

Exploitive, Opportunity-Seeking

Normative, Goal-Oriented.

All four modes of planning may be considered as versions of the general approach illustrated in Figure 10.1. The central box represents the urban system. This is composed of individuals and institutions, co-existing in an environment of interacting natural and cultural processes and possessing an established set of values. Three types of inputs may act on the urban system; external forces, private interests and public policies. The potential outputs are desirable and undesirable results.

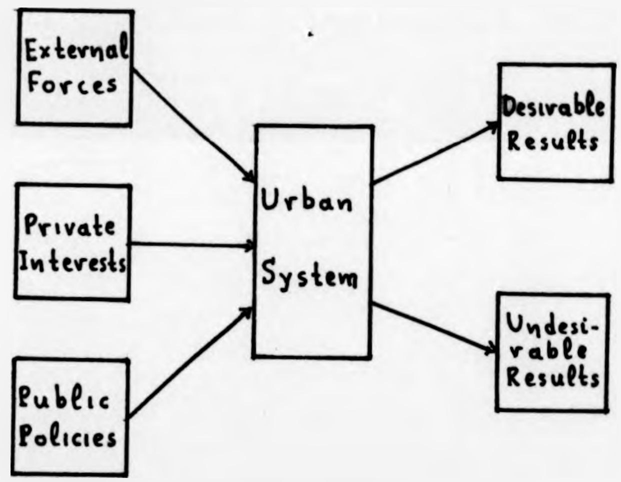

Figure 10.1

A General Urban Planning Model

Ameliorative, problem-solving (Figure 10.2), is essentially planning for present concerns. Nothing is really done until problems arise that demand corrective action and even in this case the implied goal is only the smoothing out of those problems and the preservation of the existing values.

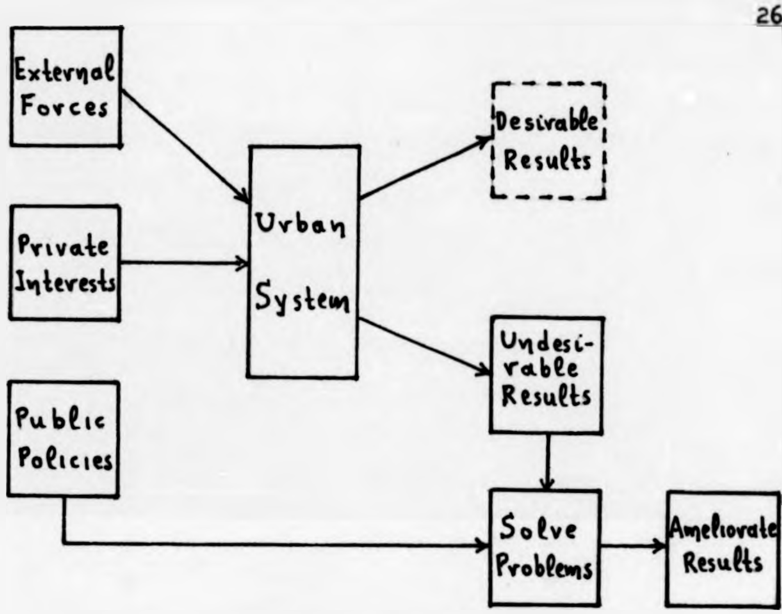

Figure 10.2

Problem-Solving Mode of Planning

Allocative, trend-modifying (Figure 10.3), is the future--oriented version of the previous mode. The present trends are projected into the future, potential problems are forecast and regulatory mechanisms are introduced to avoid the future problems while preserving the existing values.

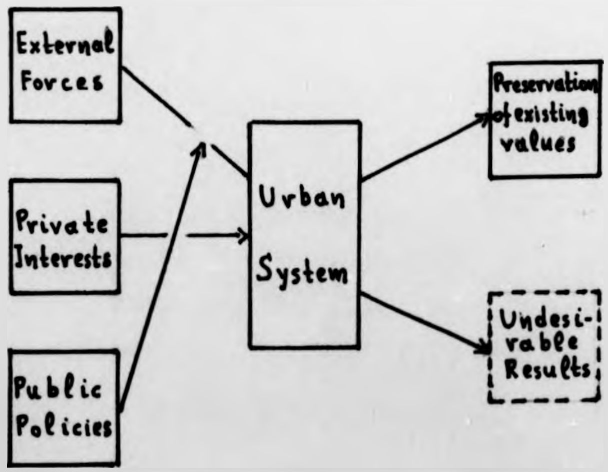

Figure 10.3

Trend-Modifying Mode of Planning

Exploitive, opportunity-seeking (Figure 10.4) is also a mode of planning responding to predicted future. The main goal in this case, however, is not to avoid any future shortcomings but to seek new growth opportunities without major concern for the potential emergence of new problems.

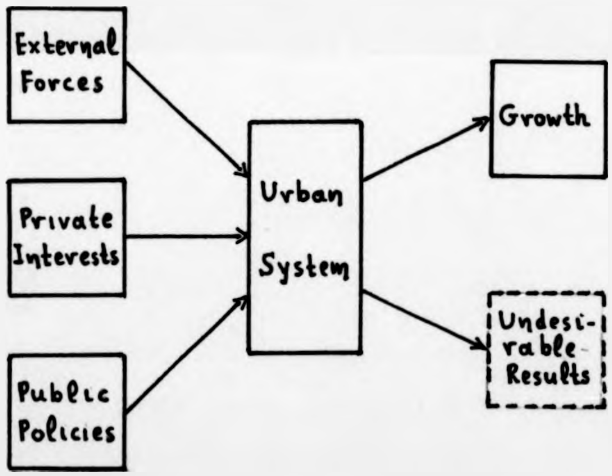

Figure 10.4

Opportunity-Seeking Mode of Planning

Normative, goal-oriented (Figure 10.5), is the only mode of planning aiming at the creation of a desired future. Goals are defined and policies are designed and implemented to guide the system towards these goals or indeed change the system if it cannot achieve them. This mode of planning obviously requires sufficient control and coercive power to ensure that the chosen plans are implemented.

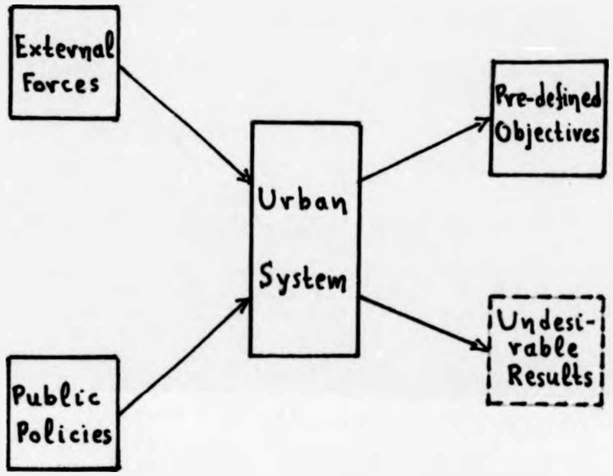

Figure 10.5

Goal-Oriented Mode of Planning

The long-term results of the four modes of planning may vary considerably. Although a mixture of some, or all four, planning styles is inevitable in any real situation, the corresponding value-system determines the preferred planning mode which regulates the process of urbanisation.

10.1 THE ROLE OF MODELS IN PLANNING

The problems that planners face today are too complex to be solved either by a speculative approach based solely on experience and intuition or by an analytical approach focussing on specific aspects of the problem concerned. The central feature of recent work in urban planning has been a movement towards a more scientific approach involving disciplines such as mathematics, operational research and systems analysis. In terms of the new approach the planning process may be structured into the following four stages:(Lee[2])

System description and Problem Definition.

Solution Generation and Analysis.

Evaluation and Choice.

Implementation and Monitoring.

Urban-system models play an important role in the urban planning process and their use can be of assistance in all its stages. They provide a rigorous and systematic exposition of the relationships between the different elements of the urban system and allow the planner better insight into it. They also facilitate the assessment of the various alternative plans and they help the planners during the implementation of the chosen solution. Urban models have brought an "externalisation" of our understanding of the city; thus,our understanding "can be criticised in an orderly and accumulative way which makes planning a morally responsible discipline" (Echenique[3]). The externalisation" process is not confined to the understanding of how the city works but also exposes the planner's ideologies, thus making possible a rational discussion of the effect of his actions on the different sections of society. Systems models, however, should not be seen as a substitute for planners; on the contrary they must be seen as a technique useful in any form of planning wherein the role of planners and the objectives of the process are made explicit.

10.3 PROPERTIES OF A PLANNING MODEL

Descriptive models are of great scientific value because they analyse the structure of the urban environment, by reducing the complexities of the real world to the coherent and rigorous language of mathematical relationships. However, although they are capable of describing or reproducing an urban system they are not necessarily capable of prediction and planning. In the words of I. Lowry[4], "Descriptive models do not directly satisfy the planner's demand for information about the future or help him to choose among alternative programs. For these purposes he must look to ... predictive and planning models". Predictive and planning models because they are required to simulate future rather than current situations, have much more stringent requirements than descriptive ones. A list of the minimum basic requirements is given below:

(i) The model structure must be time-invariant. In other words the model must contain only relationships that may be expected to remain reasonably constant over time.

(ii) The cause and effect phenomena must take up their proper roles. In cases where cause and effect cannot be clearly separated the result must be interpreted with caution.

(iii) Facilities for the testing of various alternative policies must be available.

(iv) All the exogenous variables used in the model must be reasonably easy to evaluate as far into the future as necessary.

The four requirements presented so far are sufficient for a predictive model. Indeed, the last requirement may even be partly relaxed in the case of conditional prediction, when the planner is interested in the reaction of the system following a specified act of his part. Planning models may be considered as extensions to prediction models in the sense that "they are constructed in such a way as to tell us not simply what is likely to happen as a result of certain assumptions, but rather what range of performance is possible in relation to defined objectives" (Lee[2]). Hence, a planning model has the following further requirement:

(v) A measure of the system's performance and the necessary constraints must be built into it. In a general context, a planning model should always take the following form (Ackoff[5]) :

$$V = f(x_i, y_i)$$

where,

V = the measure of the system's performance.

x_i = the controllable variables.

y_i = the parameters i.e. variables not subject to control by the decision maker.

f = the fundamental time-invariant relationship between dependent and independent variables.

The model presented in the last five chapters satisfies all five requirements of a planning model. The structure is time invariant; the cause and effect phenomena have been carefully separated; all the variables can be evaluated into the future; a measure of the system's performance has been introduced in the form of the Basic Image and finally various control programs have been included for testing the effects of different policies on the performance of the urban system. Therefore, the proposed model may be used for planning or in other words to enable us to determine what values of the controllable variables (i.e. which urban programs) provide the maximum value of the Basic Image . Finally, several constraints regarding the maximisation of the Basic Image have also been included. They cover problems concerning mainly finance and manpower both within the city and the wider surrounding region. Details are given in Chapter 8.

Having presented a general assessment of the planning potential of my model, in the remaining part of this chapter I shall discuss the mode of planning in various parts of the world and also the modifications required if this model is to be applied in any of them.

10.4 THE CASE OF BRITAIN AND THE WESTERN EUROPE

10.4.1 The Mode of Planning

In Western Europe the reaction against the laissez-faire ideology of the 19th century resulted to the emergence of the so-called welfare system. The distinctive feature of this system was the use of Government power for the reduction of socio-economic inequalities, among the various groups of the country's population and the provision of an acceptable minimum of material welfare to every person. In urban terms, the first real step towards an alternative to uncontrolled urbanisation was the publication in 1878 of E.Howard's[6] book "Tomorrow: A Peaceful Path to Real Reform" which was revised in 1902 as "Garden Cities of Tomorrow". The essential aim of the Garden City was to provide a juster, saner, healthier and more efficient alternative to the badly planned, badly built and over-crowded products of uncontrolled industrial urbanisation. The publication of the book created a strong drive for the improvement of city-life and two Garden Cities, Letchworth and Welwyn Garden City, were built in England in 1903 and 1920 respectively.

The two World Wars created further urban problems but in the post-war period most Western European Governments emerged with increased powers and stronger commitment to control them. At this stage, two dominant ideologies in European urban planning appeared. In Britain, the concept of New Town was aimed at a better balance between town and country. The major objective of the New Towns was to provide human-scaled, self-contained and balanced communities for working and living. In France on the other hand, the concept of "grand ensemble" favoured the large concentrations of population, the apartment house and the higher density of living it represents. The writings and work of E. Howard and L. Mumford on the one hand and Le Corbusier on the other, underline those two main scools of thoughts.

Despite differences in form, however, the birth of the welfare state meant that after a long period of uncontrolled growth in Europe, the need for objectives giving priority to the social welfare of every city's inhabitants was realised and measures for the implementation of those objectives were introduced. Although the exact goals of urban development policies differ from country to country, the following three objectives are to a large extent common to all welfare-states.

(i) Balanced economic and social development for the various regions of the country.

(ii) Balanced distribution of economic resources and social amenities among the various groups of a city's inhabitants.

(iii) Environmental protection.

As in the case of the objectives of urban policies the means employed for their implementation vary from country to country. A common characteristic, however, of these urban control mechanisms is that they are essentially negative. Although they can usually prevent an undesired event, they are rather unsuccessful in achieving a desired one. Industrial Development Certificates, which have been used extensively in Britain, are a typical example of such a negative control mechanism. By using them,the Board of Trade can prevent industrialists from going where it does not want them but it cannot compel them to go where it does want them (Lee[7]).

Despite those limitations however,public involvement in urbanisation has been constructive. By directing society towards goals of redistribution and equity,the competitive drive is reorientated and urbanisation is deliberately led in new directions. In terms of the four modes of planning described in section 10.1,the welfare states of Western Europe may be considered as applying a mixture of opportunity-seeking and goal-oriented planning.

10.4.2 Applicability of the Proposed Model

The model presented in the last five chapters has been built upon experience gained from the study of the growth and decline of British industrial cities and data collected for them. Most North and Western European countries, have followed a similar socio--economic development during the last century and their mode ofplanning is also similar. Therefore, the proposed model should be easily applicable to any Western European country with only minor structural modifications. Since balanced socio-economic development for the various regions is among the objective of urban planning in Western Europe,the use of constraints upon the interaction of every city with the rest of the country is essential. The strength of the constraints obviously depends on the particular country, and the relative weight given to regional equity as against national economic efficiency at a given time. In recent years,attempts to tackle regional inequalities on an international level basis have been initiasired one. Industrial Development Certificates, which have been used extensively in Britain, are a typical example of such a negative control mechanism. By using them, the Board of Trade can prevent industrialists from going where it does not want them but it cannot compel them to go where it does want them (Lee[7]).

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10.5 THE CASE OF NORTH AMERICA

10.5.1 The Mode of Planning

In North America the reaction against the laissez-faire ideology of the 19th century has been much milder than in Western Europe. Even today, the classical 19th century model remains, to a large extent, the basis of the North America socio-political structure. Consequently, public involvement is very limited and its main role is to protect the traditional mainstream social values as privately initiated innovation produces social change.

This attitude towards social change has been clearly reflected in the American mode of planning, which has been a mixture of ameliorative and opportunity seeking. The construction of new towns is a typical example of this approach. After a rather disappointing start in the 1920s the idea of new towns gained considerable support; almost 50 new towns were founded during the period 1960-1970 alone, mainly in areas of rapid growth and mild climate. The major driving force behind those projects, however, was private initiative. The builders and developers of all those towns were all private groups -called the "new entrpreneurs"- motivated by the profit-making potentialities latent in the process of urban growth and change. Private initiative has also been dominating housing construction for a long time. The Federal Housing Administration, formed in the 1930s in order to eliminate the worst housing and to provide public housing for the poor, could only offer limited help. The 1960s saw a new effort for a more comprehensive approach of urban problems. A very important development was the Housing Act of 1968, introducing housing programs which raised significantly the relative proportion of low-cost houses. Further development was expected after the passing of the Housing and Urban Development Act of 1970, which required the President to assist the development of national urban policy by producing every other year a Report on Urban Growth. The first Report, however, published in 1972, was a disappointment for those expecting any fundamental changes. Its main conclusion was that "patterns of urban growth ... cannot be dictated" and privatism should prevail (Berry[1]).

A similar situation exists in Canada. In the words of N. Lithwick[8], "of all urban problems, the one most likely to deter any major improvements is the urban policy problem. The first priority is, thus, not what urban policy to follow but an agreement that any urban policy is needed".

Thus, it is clear that in North America there is no explicit national policy to plan and direct urban development. What does exist, is a set of public policies mildly regulating privately initiated process.

10.5.1 Applicability of the Proposed Model

The rather individualistic approach of urban planning in North America suggests that if the proposed model is to be used there several structural modifications are required concerning the various aspects of Government intervention. The basic change however, must be in the way of modelling the interaction of the city under consideration with the rest of the country and considerable relaxation of the relevant constraints may be needed. A typical example of this approach is Forrester's[9] model. The implicit objective of this model is the unconstrained growth of the city; hence, programs -such as

Labour-Training or Low-Cost Housing provision- which contribute towards a general societal improvement but at a relative cost to the city itself are considered as failures. This approach to planning implies a "limitless" environment and the dangerous implications of this assumption have already been discussed in section 8.12.

10.6 THE CASE OF SOVIET UNION AND EASTERN EUROPE

10.6.1 The Mode of Planning

Contrary to the case of North America the reaction ofthe Soviet Union and Eastern Europe in general,against the laissez-faire ideology and its undesired consequences was very drastic indeed. Although Russia had not undergone an extensive industrialisation process itself at the time of the Communist Revolution, the classic writings of Marx which inspired the Revolution were based on the author's experience gained from the study of the process of Western European industrialisation. Hence, the Russian Revolution of 1917 may be considered as an indirect reaction against the consequences of industrialisation under laissez-faire; a reaction which marked the birth of a new political system,aiming to reform the society through a state monopoly of production of goods, of means of communications, of education and of science.

In terms of urban development,the new political system sought a new pattern of human settlement, the city of socialism. The main objectivesof the socialist city are the abolition of social and economic divisions among the various groups of people and the provision of decent housing and a wide range of social services. Strict planning was also introduced for the implementation of predetermined national pattern of industrial location and the regulation of the rate

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Although the goals of the socialist city seem rather similar to those of the welfare city,the methods used for their achievement differ considerably in the two cases. Whereas in the welfare state mostly negative control mechanisms are used to direct urban development towards new objectives, in the case of the socialist state control mechanisms are used to make sure that the urban development follows the pre-set odjectives. Planning in Eastern Europe may be seen as normative and goal-oriented. In the case of the Soviet Union, for example, the State Planning Commission determines the economic norms of the city and the basic employment required. Taking that as a base,the only task of the city planner is to implement existing norms, also determined by the Central Planning Authorities and laid out in national basic books of standards. In many cases, however, practical difficulties make the full implementation of those norms impossible.

Although planning, or commanding, with positive control mechanisms, makes the task of the planner much easier the question of the desiredurban future in Eastern Europe is far from solved. The widelypublicised debate between two Russians scolars, the geographer B.S. Khorer advocating reduction of city size, and the economist V.V. Perevedentser favouring the growth of larger cities, underlines the sort of major arguments in Eastern Europe. At the moment,however, it seems likely that the trend of concentration of population in large cities will continue, at least for a while, in Eastern Europe at a time when planned decentralisation transforms urban areas in Western Europe (Berry[1]).

10.6.2 <u>Applicability of the Proposed Model</u>

The case of Eastern Europe is radically different than those of Western Europe and North America. The movement of people and especially industry is not voluntary but state-controlled. Therefore, the concept of a city's Basic Image, and consequently an urban model based on it, is irrelevant and indeed inapplicable in this case, simply because it presupposes voluntary movement and free choice.

10.7 THE CASE OF UNDERDEVELOPED COUNTRIES

An urbanisation process involving even greater number of people than in the 19th century Europe, has been taking place in the countries of the Third World during the last few decades and various attempts to plan it are being made. Effective planning of the process of urban development in a Third World country requires a clear understanding of the mechanisms generating it. Most of the planning models used in the Third World today, implicitly assume that this process is identical to the European urbanisation process; consequently, they are built on the basis of empirical evidence from the European experience. Such an assumption, however, may prove misleading; although the two processes display certain similarities, they also display certain fundamental differences which suggest that a distinct approach of modelling and planning is required in each case. The main differences are as follows:

(i) Urbanisation in the Third World involves countries with the lowest levels of economic development whereas in the West it involved countries with the highest levels at the time.

(ii) The availability of relative advanced medical care makes death rate in general, and infant mortality in particular, much lower in the cities of the Third World than it was in the first industrial cities of Western Europe and North America.

(iii) Institutional settings and regulations which were the natural consequences of the industrialisation process in Europe have preceded it in the Third World.

(iv) Advanced means of communication and transportation enables people of the underdeveloped countries to "discover" the significantly higher standards of living enjoyed by the citizens of the industrially developed nations.

As a result of (i) and (ii) industrialisation in the Third World lags far behind the rate of urbanisation; this leads to far more severe employment and housing problems for the bulk of new urban residents than those encountered by their counterparts in Europe. As a result of (iii) and (iv), on the other hand, the pressure for rapid social change in the Third World is likely to be much greater than Western experience might suggest.

Concluding I may say that the proposed model may be applied to an underdeveloped country provided that certain modifications are introduced concerning the following aspects:

(i) The changes in the coefficients of the Image Equation i.e. the movement of the cusp.

(ii) The Housing Sector.

(iii) The Employment Sector.

The use and the strength of constraints upon the interaction of the city with its surrounding environment depend on the particular country and the planning mode it chooses to adopt.

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PART III

Testing of the Model

Chapter 11

Validating the Use of Basic Image in Modelling Urban Development

11.1 INTRODUCTION

Part II presented the model and discussed its potential uses. Part III is devoted to its testing. More precisely Chapter 11 justifies the use of the concept of Basic Image in modelling urban growth by testing the four non-mathematical hypotheses concerning the shape of its graph; those hypotheses were firstly presented in Chapter 3 and they are restated below. Chapter 12 examines the descriptive power of the model which has been built upon the concepts of Basic and Specific Image. Figures 11.1 and 11.2 illustrate graphically the objectives of the two Chapters. The objective of Chapter 11 is to compare the trend of the Basic Image for a given city, as obtained through exogenously provided data, with the trend of its actual population. The objective of Chapter 12 is to compare the trends of the main key variables for a given city, as generated endogenously by the constructed model, with their actual trends.

Let me start by restating the four non-mathematical hypotheses.

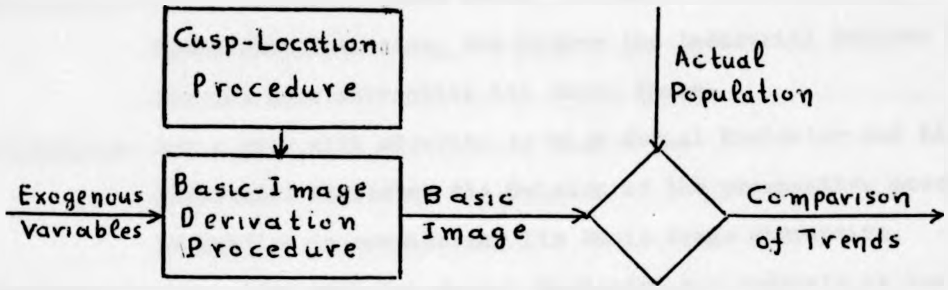

Figure 11.1

Objective of Chapter 11

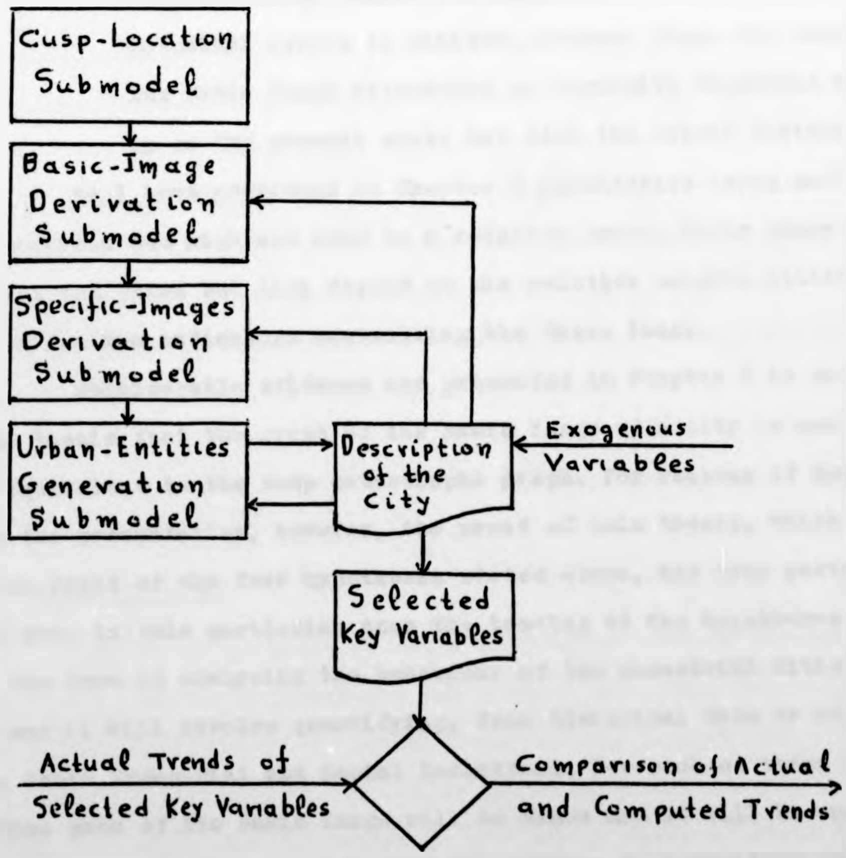

Figure 11.2

Objective of Chapter 12

HYPOTHESIS_1: For a city with fixed Social Indicator and increasing Industrial Indicator, the higher the Industrial Indicator the more attractive its Basic Image.

HYPOTHESIS_2: For a city with moderate or high Social Indicator and high Industrial Indicator the Opinion of the prospective movers is unified in considering its Basic Image attractive,

HYPOTHESIS_3: For a city with low Social Indicator and moderate or low Industrial Indicator the opinion of the prospective movers is unified in considering its Basic Image repulsive.

HYPOTHESIS_4: For a city with moderate or low Social Indicator and moderate or high Industrial Indicator the opinion of the potential movers is divided, between those who consider its Basic Image attractive or repulsive depending not only on the present state but also the recent history.

As I have mentioned in Chapter 3 quantitative terms such as low, moderate and high are used in a relative sense. Their range of values are not fixed but they depend on the relative weights attached to each of the two indicators controlling the Basic Image.

Considerable evidence was presented in Chapter 3 in support of the thesis that the graph of the Basic Image of a city is qualitatively equivalent to the cusp catastrophe graph. For reasons of continuity of the presentation, however, the proof of this thesis, which requires the proof of the four hypotheses stated above, had been postponed until now. In this particular case the testing of the hypotheses will take the form of analysing the behaviour of two industrial cities over time and it will involve quantifying, from historical data or otherwise, their Industrial and Social Indicators. For each of these cities the time path of its Basic Image will be drawn and it will be compared with the corresponding graph of its net changes of population due to migration. If the two graphs prove to be qualitatively equivalent and any disagreements can be reasonably explained, then that would be evidence for the validity of the thesis I have presented.

The cities I have chosen for the test are Oldham and Coventry; the main reasons for this particular choice are that :

(i) ...both Oldham and Coventry are typical industrial cities.

(ii)...their fortunes over the years have been quite different and that should give me the opportunity of a thorough test involving all the cases described in the four hypotheses.

Furthermore Oldham and Coventry may be considered as representatives of two large families of industrial cities. The first contains cities which flourished during the early stages of the Industrial Revolution while the second includes cities which developed at a later stage. Therefore the results obtained for Oldham and Coventry will be valid for a much larger number of cities and a verification of my thesis for those two cases may be taken as proof for it.

The test of the model covers the period 1801-1971. Efforts have been made to gather all available information —numerical data as well as descriptive material— so as to present a complete and realistic picture of the development of each city.

11.2 THE CASE OF OLDHAM

11.2.1 Brief History

Oldham is situated in South Lancashire. Before the Industrial Revolution South Lancashire was a very poor area. The soil offered little opportunity for agriculture and the farmers and their families naturally turned to the making of woollens and linens. However by 1850 Lancashire was the centre of the cotton industry while the great East Anglian cotton industry had virtually disappeared. This sudden change was the result of the much more general change in the industrial organisation of the country, namely the introduction and the rapid spreading of the factory system which took place at the same time. Lancashire could offer exactly what the new system wanted; proximity to natural resources (water and coal), land availability plus the extra bonus of freedom from all the strict restrictions which controlled industry in the older towns like Norwich and Exeter. Oldham was one of the cities which benefited much from that change (Parker [1]). The sudden increase in the value of its Industrial Indicator together with the fact that at that period Industrial Indicator was by far the dominant factor in the determination of a city's Basic Image resulted in a very rapid industrial expansion. However, the speed of that expansion and also the fact that almost no effort was made to substain reasonable living conditions for the rapidly increasing workforce resulted to an eventual decline of the city's Social Indicator. As long as the cotton industry was prospering the full effect of the declining social conditions on Oldham's Basic Image was not realised..Even as late as 1910, when first signs of decline of cotton industry were already visible and the first trends of out-migration had already appeared, the Lancashire people were still convinced of the unrivalled position of their area. In the words of Godfrey Armitage in his paper on the Lancashire cotton trade 'From the Great Inventions to the Great Disasters'; "If in the hot summer of 1914 you had said to a Lancashire man: "My dear Sir, do you realise that you stand on the edge of a precipice?" his eyes would have popped out of his head. He would have asked you to see a doctor. The advance had gone on for generations; it was a natural law: it did itself". (Chaloner[2]). Unfortunately however this conviction of Lancashire men proved to be disastrously wrong. The cotton industry entered a stage of definite decline, altough again this was not fully realised until the

1930's and the need for the attraction of new industries into the area became urgent. It was at this point that Oldham had to face the truth. Although its Industrial Indicator had remained at a reasonably above--normal level the fall of its Social Indicator together with the fact that its relative importance had increased considerably by then reduced its attraction power to below-normal levels. The critical importance of the Social Indicator is perfectly illustrated in the following extract from P.M. Fogarty's[3] book "Prospects of the Industrial Areas of Great Britain". Referring to the post-war prospects of Lancashire as a whole he writes that "from the point of view equally of transport, of labour, of marketing and of other factors of cost it appears that even the weaving district is at little or no real disadvantage by comparison with the Midlands or South. One genuine disadvantage is the generally drab appearance of the Lancashire cotton towns and the poor quality of housing and social amenities particularly from the point of view of employers, managers and officials, and imported key workers in new industries which might alternatively be located in one of the more attractive areas in the South". As a result of the fall in the value of Oldham's Basic Image a severe wave of net out-migration started, The city was left with a dispirited population and greatly reduced financial resources (in terms of rate receipts) with which it was quite unable to cope with the ever increasing problems.

The post-war period saw a relative change in the socio-political structure of Britain. The Government accepted increased responsibilities regarding the welfare of the people and several efforts were made to revive Oldham as well as many other industrial cities in depressed areas. Although those efforts have produced relative improvements in both Industrial and Social Indicators the Basic Image of

Oldham still remains unattractive.

11.2.2 Quantification of its Basic Image

Basic Image has been expressed as a function of two indicators —Industrial and Social— each of which may be further expressed as the product of three multipliers. The derivation of the two indicators is discussed below.

I. Industrial Indicator

In the case of the Industrial Indicator the three multipliers are:

Accessibility Multiplier	(ACSM)
Land Availability Multiplier	(LAVM)
Regional Industrial Multiplier	(RGIM)

Those mutlipliers have been defined in Chapter 6 and the same quantification procedure is followed here.

Accessibility Multiplier. Accessibility Multiplier for a given city depends on its Relative Accessibility Index. The form of their relationship has been given in Chapter 6. The method for deriving the Accessibility Index for any city has been described in Appendix 2; the Accessibility Index for the normal city has also been computed there. Table 11.1 presents the Accessibility Index for Oldham and the normal city as well as the Relative Accessibility Index for Oldham; the latter is computed as the fraction of the index for Oldham over that for the normal city.

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TABLE 11.1

ACCESSIBILITY INDEX (Oldham)

Year	Accessibility Index for		Relative Accessibility Index for Oldham
	Oldham	Normal City	
1801	0.53	0.32	1.65
1821	0.56	0.33	1.70
1841	0.87	0.50	1.78
1861	0.87	0.44	1.93
1881	0.92	0.58	1.59
1901	0.78	0.59	1.30
1921	1.08	0.87	1.25
1941	0.95	0.81	1.20
1961	1.05	0.92	1.19

Land Availability Multiplier. Land Availability Multiplier for a given city depends, in general, on both population density and local regulations concerning land-use; the latter are expressed through the Land Use Regulation Factor (LURF). As long as no special regulations exist (i.e. LURF = 1) the multiplier is a function only of the relative density of population within the region surrounding the city. In the opposite case it is a function of the Land Use Regulation Factor. The model assumes that for the case of Oldham no special land-use conditions exist. On the other hand the County of Lancashire reached its highest population density, 1055 persons per sq. kilometre, around 1960. (Table 11.2). Since this is clearly lower than the maximum tolerable population density as defined in Appendix 2 the Land Availability Multiplier for Oldham remains normal (i.e. LAVM = 1) over the entire period covered by the model.

TABLE 11.2

LAND AVAILABILITY (Oldham)

Year	Population Density for Lancashire	
	Absolute pers. per sq. km	Relative
1801	138	0.05
1821	216	0.09
1841	343	0.14
1861	499	0.20
1881	710	0.28
1901	900	0.36
1921	1013	0.41
1941	1031	0.41
1961	1055	0.42

Regional Industrial Multiplier. Finally the regional Industrial Multiplier for a given city is considered as a function of the relative unemployment rate of the region where it belongs. Table 11.3 presents

TABLE 11.3

UNEMPLOYMENT RATE (North West)

Time-Period	Unemployment Rate for		Relative Unemployment Rate for North West
	North West	National Average	
1801-1921	n.a	n.a	(1.00)
1921-1931	18.55	12.40	1.50
1931-1941	21.30	16.16	1.32
1941-1951	1.73	1.40	1.24
1951-1961	2.02	1.45	1.39
1961-1971	2.27	1.93	1.18

unemployment rate of the region where it belongs. Table 11.3 presents the normal unemployment rate and that for the North-Western region over the period 1921-1971. Regional Rates did not become available until 1920; for the purposes of the model Regional Industrial Multiplier for Oldham as indeed for every city, is taken as normal for the period 1801-1921.

Having presented the three control factors I can now generate the Industrial Indicator for the city of Oldham. Table 11.4 presents the values of the three multipliers and the value of the indicator it-

TABLE 11.4

INDUSTRIAL INDICATOR (Oldham)

Year	ACSM	LAVM	RGIM	II
1801	2.540	1.000	1.000	1.364
11	2.630	1.000	1.000	1.380
21	2.720	1.000	1.000	1.396
31	2.864	1.000	1.000	1.420
41	2.996	1.000	1.000	1.442
51	3.236	1.000	1.000	1.479
61	3.476	1.000	1.000	1.515
71	2.932	1.000	1.000	1.431
81	2.324	1.000	1.000	1.325
91	1.824	1.000	1.000	1.222
1901	1.360	1.000	1.000	1.108
11	1.280	1.000	1.000	1.086
21	1.200	1.0000	1.300	1.160
31	1.180	1.000	1.228	1.132
41	1.160	1.000	1.192	1.114
51	1.156	1.000	1.256	1.132
61	1.152	1.000	1.144	1.096
71	1.152	1.000	1.144	1.096

KEY

ACSM: Accessibility Multiplier; LAVM: Land Availability Multiplier

RGIM: Regional Industrial Multiplier; II: Industrial Indicator.

self for the period 1801-1971. The formula used for the derivation of the Industrial Indicator given the values of its three multipliers has been described in Chapter 6.

II. Social Indicator

This has been expressed as a function of the following multipliers:

Housing Multiplier (HSM)
Environmental Multiplier (ENVM)
Regional Social Multiplier (RGSM)

All three multipliers have been defined in Chapter 6. For the purposes of the model the quantities required for their derivation are generated endogenously; data for their exogenous computation is not generally available in the required form. For the case of this test the nearest possible available quantities will be used. The relationships between them and the corresponding multipliers will be taken as identical to their counterparts presented in Chapter 6. Even for those quantities, however, consistent and reliable data are available for the latter part of the analysed period. Our knowledge of the first part is based mainly on information from historical surveys and relevant descriptive material.

Housing Multiplier. It is generally accepted that living conditions in cities which developed rapidly during the early stages of the Industrial Revolution reached a very low level in the second half of the 19th century. Back to back houses in dark overcrowded courts and narrow alleys were a common feature of any industrial city. Oldham was one of them. Early censuses classify Oldham among the cities with the higher proportion of houses with less than 5 rooms (appr. 700% as compared with 100-200% for cities like Leicester or Derby). High proportion of small houses was at that time an indication of overcrowding since the average family size was well over five. The first tangible piece of evidence however, appears in the census of 1901. According to it 7.4% of Oldham population were living in overcrowded conditions as compared to an average of 6.5%. Subsequent censuses express overcrowding as the number of persons per room. The available data is summarised in Table 11.5 which is used as the basis for the derivation of the Fit Housing Availability Multiplier (FHAVM) Table 11.6. Values of FHAVM for the period 1801-1901 are obtained by assuming "normal" overcrowding at 1801 and a linear increase to its level of 1901.

TABLE 11.5

OVERCROWDING (Oldham)

Year	Number of Persons per room		Relative Number of persons per room for Oldham
	Oldham	National Average	
1911	1.01	0.95	1.06
1921	0.99	0.91	1.09
1931	0.89	0.83	1.05
1941	n.a	n.a	n.a
1951	0.76	0.74	1.03
1961	0.67	0.68	0.99

TABLE 11.6

FIT HOUSING AVAILABILITY MULTIPLIER (Oldham)

Year	1801	1811	1821	1831	1841	1851	1861	1871	1881
FHAVM	1.00	0.95	0.90	0.86	0.82	0.77	0.73	0.69	0.64

TABLE 11.6 (cont.)

Year	1891	1901	1911	1921	1931	1941	1951	1961	1971
FHAVM	0.60	0.55	0.58	0.54	0.68	(0.73)	0.77	1.08	1.08

Consistent data on housing quality is not available. Housing quality indicators were not introduced until the census of 1951. Therefore only an indirect evaluation of Oldham's housing stock is possible. Local Government returns in 1965 gave the proportion of Unfit Houses in Oldham as 12-12.5%; this compares with an average of around 5.5%. Using the Housing Quality Scale described in Chapter 6 such a percentage of Unfit Housing Units corresponds to a Housing Quality Index of around 0.7 times that of the normal city. Housing stock of low quality is usually associated with declining cities. Therefore assuming a normal value for Oldham's Housing Quality Index up to 1901 and a linear fall to its present-day level thereafter I estimate the Housing Quality Multiplier for the period 1801-1971 (Table 11.7).

TABLE 11.7

HOUSING QUALITY MULTIPLIER (Oldham)

Year	1901	1911	1921	1931	1941	1951	1961	1971
HQLM	1.00	0.92	0.84	0.75	0.68	0.60	0.52	0.44

Environmental Multiplier. Environmental quality of rapidly growing cities had declined considerably by the second half of the 19th century. Sanitary arrangements such as drainage systems, fresh water supply and removal of refuse were not even thought until 1840 and by the time the first attempts for their implementation were made the living conditions of the labouring masses had become appaling. Furthermore, factory the nucleus of every industrial city was claiming and eventually spoiling the best sites and water resources. Meaningful data on pollution are practically unobtainable even today. Pollution, however, is in general connected with excessive industrial activity and overcrowding. For the purposes of this test pollution will be taken as following the trend of overcrowding. Regarding the question of dereliction Local Government returns in 1966 gave the proportion of derelict land in the County of Lancashire as 0.90-0.95%; this compares with the national average of around 0.3% (Barr[4]). In other words Lancashire contains a proportion of derelict land approximately 3 times higher than the national average. For lack of more specific data this is also taken to represent the situation in the city of Oldham alone. Dereliction is usually associated with a declining city. Therefore by assuming a normal proportion of derelict land up to 1901 and a linear increase to its present-day level threafter I can estimate the Townscape Quality Multiplier for the period 1801-1971 (Table 11.8).

TABLE 11.8

TOWNSCAPE QUALITY MULTIPLIER (Oldham)

Year	1901	1911	1921	1931	1941	1951	1961	1971
TSQM	1.00	0.93	0.85	0.77	0.71	0.63	0.56	(0.48)

<u>Regional Social Multiplier</u>. Like the Regional Industrial Multiplier the Regional Multiplier of a given city depends also on the relative unemployment rate of the region it belongs. The normal unemployment rate and that for the North-Western region have already been presented in Table 11.3. Regional unemployment rates are not available for the period 1801-1921 and the Regional Social Multiplier for Oldham as indeed for every city is taken as normal for that period.

TABLE 11.9

SOCIAL INDICATOR (Oldham)

Year	HSM	ENVM	RGSM	SI
1801	1.00	1.00	1.00	1.00
11.	0.95	0.95	1.00	0.97
21	0.90	0.90	1.00	0.93
31	0.86	0.86	1.00	0.91
41	0.82	0.82	1.00	0.88
51	0.77	0.77	1.00	0.84
61	0.73	0.73	1.00	0.81
71	0.69	0.69	1.00	0.78
81	0.64	0.64	1.00	0.74
91	0.60	0.60	1.00	0.71
1901	0.55	0.55	1.00	0.67
11	0.58	0.58	1.00	0.69
21	0.54	0.54	1.00	0.66
31	0.68	0.68	0.60	0.65
41	0.68	0.71	0.71	0.70
51	0.60	0.63	0.80	0.66
61	0.52	0.56	0.65	0.57
71	0.44	0.48	0.82	0.56

<u>KEY</u>

HSM: Housing Multiplier; ENVM: Environmental Multiplier;
RGSM: Regional Social Multiplier; SI: Social Indicator;

On the basis of the presented information I am now in a position to generate the Social Indicator for the city of Oldham. Table 11.9 presents the values of the three multipliers controlling the Social Indicator and also the value of the Social Indicator itself for the period 1801-1971. The relationship between the three multipliers and the Social Indicator has been defined in Chapter 6.

11.2.3 Comparing the time-path of the Basic Image with the trend of Population changes

I have so far generated both Indicators for the city of Oldham for the period 1801-1971. By plotting their values – as presented in Tables 11.4 and 11.9 – I can draw the time-path of its Basic Image over the same period.(Figure 11.3). The presence of more than one cusp in Figure 11.3 indicates the dynamic nature of the concept of a city's image or in other words the changes in the relative weights attached to the two indicators. The movement of the cusp has been discussed in Chapter 5 and it has been modelled as a continuous process. For the purposes of this test however, I approximate the continuous movement of the cusp by a sequence of discrete positions of its axis and I consider only four of them. The first position ($\theta = 80^\circ$) corresponds to the year 1800. The second ($\theta = 70^\circ$) corresponds to the year 1850 the third position ($\theta = 45^\circ$) corresponds to the year 1900 and finally the fourth ($\theta = 30^\circ$) to the year 1950. The relative positions of those four cusps are based on evidence presented in Chapter 5. For the period of time between any two successive positions of the cusp I assume that it is moving upwards until it reaches its next fixed position.

Table 11.10 gives the population of Oldham for the period 1801-1971. Table 11.11 shows the rate of population changes due to

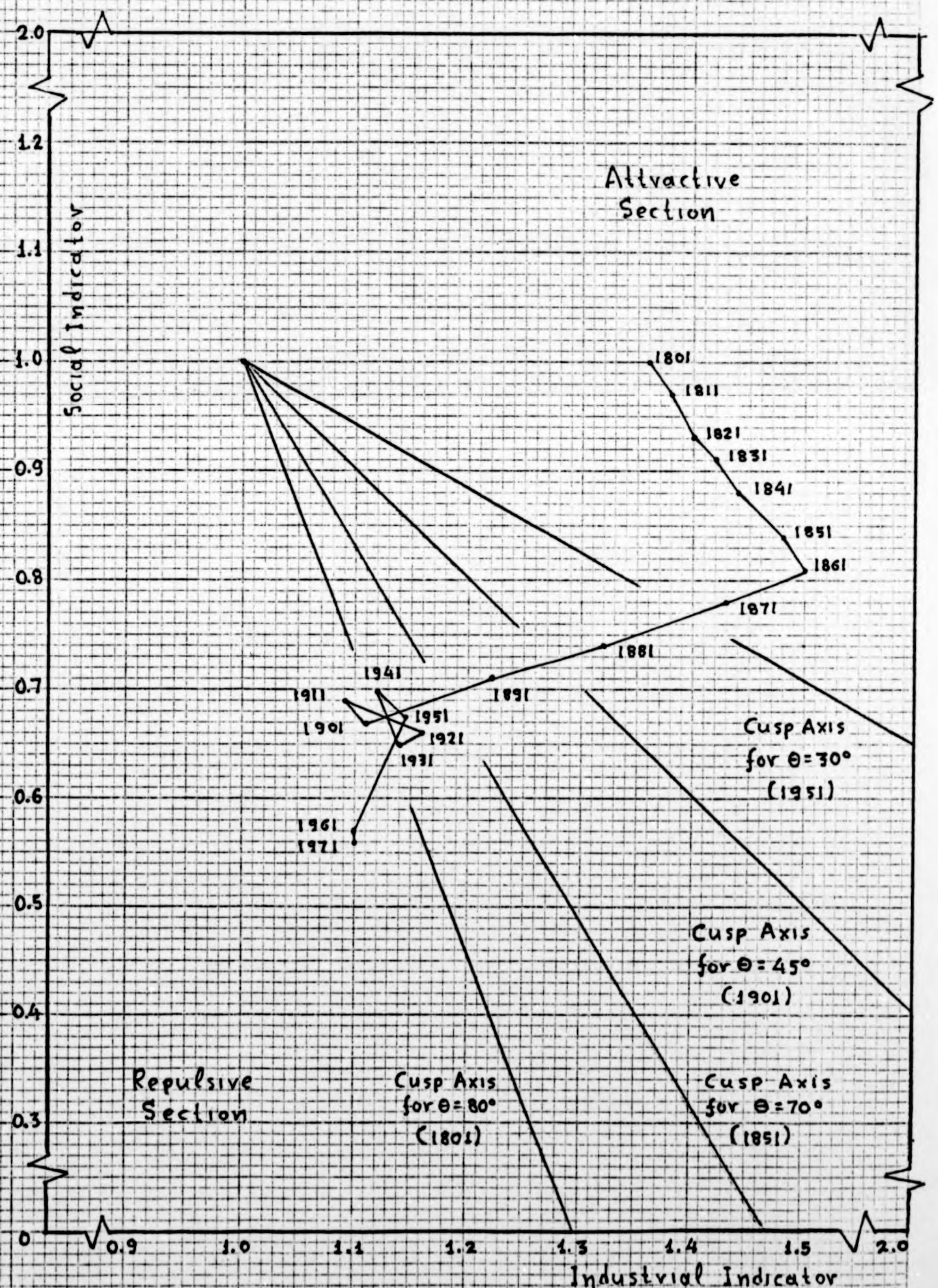

Figure 11.3

Time-Path for Oldham's Basic Image

migration only over the same period. Figure 11.4 illustrates graphically the trend shown in Table 11.11.

TABLE 11.10

POPULATION (Oldham)

Year	Population
1801	12,000
11	17,000
21	22,000
31	32,000
41	43,000
51	53,000
61	70,000
71	83,000
81	111,000
91	131,000
1901	137,000
11	145,000
21	143,000
31	140,000
41	
51	125,000
61	117,000
71	106,000

TABLE 11.11

POPULATION CHANGES (Oldham)

Time Period	Rate of Population changes due to Migration only
1801-1811	2.20
1811-1821	0.94
1821-1831	2.34
1831-1841	1.64
1841-1851	0.91
1851-1861	1.98
1861-1871	0.18
1871-1881	1.60
1881-1891	0.56
1891-1901	-0.70
1901-1911	-0.33
1911-1921	-0.63
1921-1931	-0.88
1931-1941	-1.17
1941-1951	-1.20
1951-1961	-1.19
1961-1971	-1.34

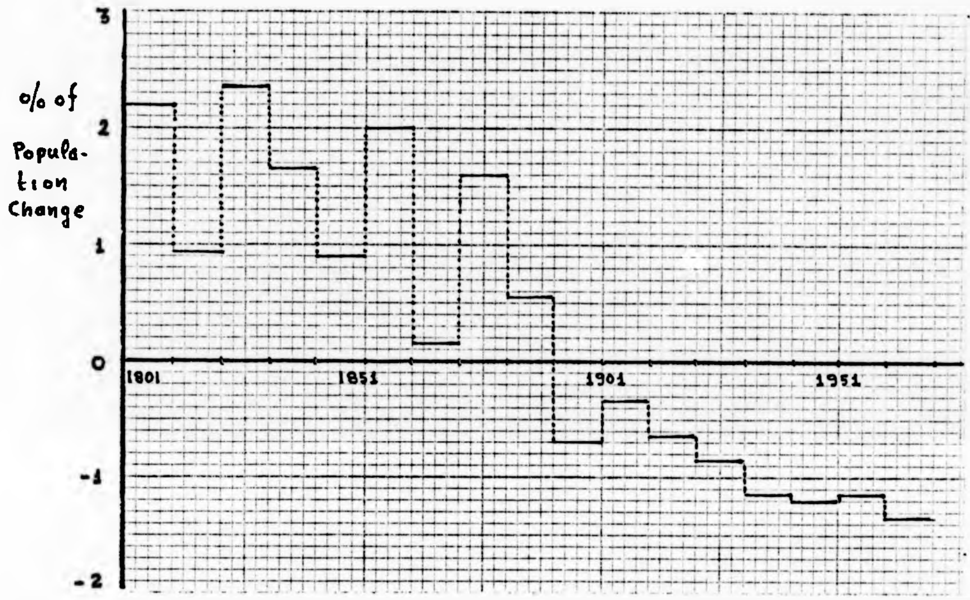

Figure 11.4 Rate of population changes due to Migration

Comparing the two graphs shown in Figures 11.3 and 11.4 respectively the following conclusions may be drawn.

Period 1800-1890 (High Industrial Indicator, Moderate Social Indicator — Hypothesis 2): The two graphs display a complete agreement over the period 1800-1890. The time-path (Figure 11.3) remains always on the Attractive Section while Figure 11.4 shows a continuous net in-migration of population.

Period 1890-1910 (High/Moderate Industrial Indicator, Moderate/Low Social Indicator — Hypothesis 4): The period 1890-1910 is also one of complete agreement between the two graphs. The time-path crosses the cusp, which by then closer to its third position, and enters the repulsive Section; Figure 11.4 shows a sudden change from a situation of net in-migration to a situation of net out migration. The breaking point for the time path has not been defined exactly but for the purposes of this test, a reasonable approximation is sufficient.

Period 1910-1970 (Moderate Industrial Indicator, Moderate Social Indicator — Hypothesis 3): The complete agreement of the two graphs continues over the period 1910-1970. The time-path remains always on the Repulsive Section while Figure 11.4 shows a continuous out-migration of population during the entire period.

Summarising the comparisons of the two graphs I can say that they have shown a remarkable degree of agreement over the period 1801-1971 and they may be considered as qualitatively equivalent. It would therefore be fair to claim that the time-path of Oldham drawn in a way consistent with the four sociological hypotheses presents an accurate picture of the city's development.

11.3 THE CASE OF COVENTRY

11.3.1 Brief History

Coventry, the second city to be used for my test, is situated in the West Midlands. It lay naturally at the centre of the roads of Medieval England and that was the main reason for its growth in the Middle Ages when it became the fourth largest town in the country. As long as industry was based upon wool, Coventry could fairly claim to be the industrial centre of the Midlands but in the new era of Industrial Revolution, it soon lost its plase to Birmingham and the Black Country. Bradford's survey of Coventry in 1748 shows spacious gardens at the rear of the majority of the houses and depicts a city environed on all sides by open fields, namely the Commons and the Lammas and Michaelmas Lands (Smith[5]). Lammas and Michaelmas Lands have influenced the life of Coventry throughout history and not least in the era of Industrial Revolution. Although they secured a healthy environment for the city's inhabitants they also imposed a severe restriction on the use of land for industrial expansion which lasted in some form or another up to 1870. This restriction together with the relative shortage of natural resources — or in ither words the low value of Coventry's Industrial Indicator— were the main reasons for its slow growth during the early stages of Industrial Revolution (Prest[6]). The fact that the value of its Social Indicator was at the same time relatively high (definitely much higher than that of Oldham) made little difference because the influence of the Social Indicator in determining the Basic Image of a city was at that time of minimal importance. The growth of Coventry, therefore, during the period 1800-1850 was much less spectacular than the growth of Oldham or Birmingham. Its main industry during that period was the ribbon manufacturing industry. Up to 1826 all foreign imports of ribbon were prohibited and the industry free from any competition was prospering. The first difficulties appeared when tariffs substituted the prohibition of foreign imports (1826) and the situation became desperate when Gladstone announced the complete removal of the protective duty on foreign imports (1860) (Richardson[7]). The collapse of the ribbon industry followed almost immediately. The blow of the decline of its main industry, although heavy for Coventry, was considerably softened by the fact that measures had been taken to diversify the industrial basis of the city by investing in the watchmaking industry. The fact that in the 1830s 48% of the apprentices went into weaving and 28% into the watchmaking while by the 1850s the percentages were 20% and 54% respectively shows the degree of the attempted diversfisation (Prest[6]). Although watch making could offer alternative employment to some people who had lost their jobs it soon became obvious that more new industries were e required if the city was to survive. Fortunately for

Coventry the restrictions on land-use were soon lifted. The resulting increase in the value of its Basic Image together with the availability of a nucleus of skilled workers attracted the new engineering industries. The quick inflow of new industries and the rapid increase of population resulted in a decline of the city's social conditions. The development of slums in Coventry, however, coincided with a national awakening of concern about the effect of overcrowding and the lack of sanitation on public health (Richardson[7]). At the same time the relative weight of the Social Indicator in determining the Basic Image of a city started increasing. Coventry however, unlike Oldham, was in a position to respond effectively to this changing situation. Going through a period of prosperity already it could easily find the resources for tackling the new problems and improving its image. The two wars brought more manufacturing industries to Coventry and in spite of heavy damages suffered during the Second World War Coventry appeared in the post-war period once more the booming city. Overdependence however, on the car manufacturing industry, which has been going lately through a period of recession, together with the fact that Government policies during the last decade or so have tended to discourage industries from moving into Coventry, have led to a relative decline in the city's Image.

11.3.2 Quantification of its Basic Image

I. Industrial Indicator

The quantification procedure for Coventry's Industrial Indicator is very similar to that employed for the case of Oldham. Tables 11.12 and 11.14 are similar to their counterparts presented in the previous section. The only difference concerns the factor of land availability (Table 11.13). Coventry is a special case in this respect. The existence of the Lammas and Michaelmas lands proved an ad-

TABLE 11.14

UNEMPLOYMENT RATE (W. Midlands)

Time-Period	Unemployment Rate for		Relative Unemployment Rate for W. Midlands
	W. Midlands	National Average	
1801-1921	n.a	n.a	1.00
1921-1931	12.00	12.40	0.97
1931-1941	14.04	16.16	0.87

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ring the periods 1800-1820 and 1860-1880 (when their relaxation was under way) reduced the LAVM to ½ of its normal value. The reduction was up to 50% during the period 1820-1860. For the period 1880-1970 LAVM is given as a function of the population density within the surrounding region. The County of Warwickshire reached its highest population density (796 persons per sq. kilometre) around 1960. Since this is clearly lower than the "maximum tolerable" value defined in Appendix 2 the Land Availability Multiplier remains normal (i.e. LAVM = 1) over the period 1900-1970.

As in the case of Oldham the three multipliers lead to the derivation of the Industrial Indicator (Table 11.15).

TABLE 11.14

UNEMPLOYMENT RATE (W. Midlands)

Time-Period	Unemployment Rate for		Relative Unemployment Rate for W. Midlands
	W. Midlands	National Average	
1801-1921	n.a	n.a	1.00
1921-1931	12.00	12.40	0.97
1931-1941	14.04	16.16	0.87
1941-1951	0.61	1.40	0.45
1951-1961	1.00	1.45	0.68
1961-1971	1.73	1.93	0.80

verse factor in the development of the city over the period 1800-1880. Its negative influence became stronger around 1850 when the city's limits of potential expansion had been reached. Hence for the case of Coventry the Land Availability Multiplier is given as a function of the Land-Use Restriction Factor (LURF) for the period 1800-1880. For the purposes of the model I assume that land-use restrictions during the periods 1800-1820 and 1860-1880 (when their relaxation was under way) reduced the LAVM to ½ of its normal value. The reduction was up to 50% during the period 1820-1860. For the period 1880-1970 LAVM is given as a function of the population density within the surrounding region. The County of Warwickshire reached its highest population density (796 persons per sq. kilometre) around 1960. Since this is clearly lower than the "maximum tolerable" value defined in Appendix 2 the Land Availability Multiplier remains normal (i.e. LAVM = 1) over the period 1900-1970.

As in the case of Oldham the three multipliers lead to the derivation of the Industrial Indicator (Table 11.15).

TABLE 11.14

UNEMPLOYMENT RATE (W. Midlands)

Time-Period	Unemployment Rate for		Relative Unemployment Rate for W. Midlands
	W. Midlands	National Average	
1801-1921	n.a	n.a	1.00
1921-1931	12.00	12.40	0.97
1931-1941	14.04	16.16	0.87
1941-1951	0.61	1.40	0.45
1951-1961	1.00	1.45	0.68
1961-1971	1.73	1.93	0.80

verse factor in the development of the city over the period 1800-1880. Its negative influence became stronger around 1850 when the city's limits of potential expansion had been reached. Hence for the case of Coventry the Land Availability Multiplier is given as a function of the Land-Use Restriction Factor (LURF) for the period 1800-1880. For the purposes of the model I assume that land-use restrictions during the periods 1800-1820 and 1860-1880 (when their relaxation was under way) reduced the LAVM to ½ of its normal value. The reduction was up to 50% during the period 1820-1860. For the period 1880-1970 LAVM is given as a function of the population density within the surrounding region. The County of Warwickshire reached its highest population density (796 persons per sq. kilometre) around 1960. Since this is clearly lower than the "maximum tolerable" value defined in Appendix 2 the Land Availability Multiplier remains normal (i.e. LAVM = 1) over the period 1900-1970.

As in the case of Oldham the three multipliers lead to the derivation of the Industrial Indicator (Table 11.15).

TABLE 11.15

INDUSTRIAL INDICATOR (Coventry)

Year	ACSM	LAVM	RGIM	II
1801	1.296	0.750	1.000	0.991
11	1.328	0.750	1.000	0.999
21	1.360	0.750	1.000	1.007
31	1.792	0.625	1.000	1.039
41	2.252	0.500	1.000	1.040
51	2.216	0.500	1.000	1.035
61	2.180	0.500	1.000	1.029
71	1.984	0.625	1.000	1.074
81	1.808	0.750	1.000	1.107
91	2.036	0.875	1.000	1.212
1901	2.288	1.000	1.000	1.318
11	2.612	1.000	1.000	1.377
21	2.932	1.000	0.982	1.423
31	3.076	1.000	0.922	1.416
41	3.220	1.000	0.676	1.296
51	3.140	1.000	0.814	1.367
61	3.060	1.000	0.940	1.422
71	3.060	1.000	0.940	1.422

KEY

ACSM: Accessibility Multiplier

LAVM: Land Availability Multiplier

RGIM: Regional Industrial Multiplier

II : Industrial Indicator

II. Social Indicator

The quantification prodedure for the Social Indicator is also similar to that employed for the case of Oldham and Ishall discuss it briefly.

Housing Multiplier. Coventry is one of the cities that grew slowly during the early stages of the Industrial Revolution. Although it experienced a certain degree of overcrowding (the spacious gardens of 1748 had gone by 1860 (Smith[5])) its housing conditions were considerably better than those of any fast-growing city (Richardson[7]). Table 11.16 summarises all the available data concerning Housing availability in Coventry over the period 1901-1971 and it is used as the basis for the derivation of the Fit Housing Availability Multiplier (FHAVM) over the same period. Earlier values have been estimated in the way described for the case of Oldham (Table 11.17).

TABLE 11.16

OVERCROWDING (Coventry)

Year	Number of Persons per Room		Relative Number of persons per room for Coventry
	Coventry	National Average	
1911	0.97	0.95	1.02
1921	0.95	0.91	1.04
1931	0.85	0.83	1.02
1941	n.a	n.a	n.a
1951	0.76	0.74	1.03
1961	0.71	0.68	1.04
1971	0.74	0.63	1.02

TABLE 11.17

FIT HOUSING AVAILABILITY MULTIPLIER (Coventry)

Year	1801	1811	1821	1831	1841	1851	1861	1871	1881
FHAVM	1.00	0.98	0.96	0.95	0.93	0.91	0.90	0.88	0.86

TABLE 11.17 (cont.)

Year	1891	1901	1911	1921	1931	1941	1951	1961	1971
FHAVM	0.85	0.83	0.83	0.68	0.83	(0.83)	0.83	0.68	0.83

Local Government returns in 1965 gave the proportion of Unfit houses in West Midlands as around 6.4%; this compares with a national average of around 5.5%. Furthermore if we take into account that the proportion of unfit houses in the West Midlands Conurbation (containing about 50% of the total West Midlands housing stock) is between 8-10% we can deduce that Coventry's housing stock contains about 4-5% of unfit housing units. Using the Housing Quality Scale described in Chapter 6 such a percentage of unfit houses corresponds to a Housing Quality Index of around 1.1 times that of the normal city. The Housing Quality Multiplier is obtained in the way described for the case of Oldham (Table 11.18).

TABLE 11.18

HOUSING QUALITY MULTIPLIER (Coventry)

Year	1901	1911	1921	1931	1941	1951	1961	1971
HQLM	1.00	1.03	1.06	1.09	1.12	1.15	1.17	1.20

Environmental Multiplier. Pollution and dereliction are the two factors which are considered as affecting the environmental quality of a given city. As in the case of Oldham, for the purposes of this test, pollution —for which data is practically unobtainable— will be taken as following the trend of overcrowding. Regarding the question of dereliction Local Government returns in 1965 gave the proportion of derelict land in the County of Warwickshire as around 0.2-0.25%; this compares with the national average of 0.3% (Barr[4]). In other words Warwickshire contained in 1965 a proportion of derelict land 0.75 times that of the national average. For lack of more specific data this is also taken to represent the situation in the city of Coventry alone. The Townscape Quality Multiplier is obtained in the way described for Oldham (Table 11.19)

TABLE 11.19

TOWNSCAPE QUALITY MULTIPLIER (Coventry)

Year	1901	1911	1921	1931	1941	1951	1961	1971
TSQM	1.00	1.02	1.04	1.05	1.07	1.09	1.10	(1.12)

Regional Social Multiplier. The Regional Social Multiplier of a given city is a function of the relative unemployment rate of the region where it belongs. Unemployment rates for the West Midlands region have been presented in Table 11.14.

On the basis of the evidence presented in Tables 11.18 and 11.19 I can now generate the values of the three multipliers controlling Coventry's Social Indicator and the value of the Social Indicator itself. for the period 1801-1971 (Table 11.20).

TABLE 11.20

SOCIAL INDICATOR (Coventry)

Year	HSM	ENVM	RGSM	SI
1801	1.00	1.00	1.00	1.00
11	0.98	0.98	1.00	0.99
21	0.96	0.96	1.00	0.97
31	0.95	0.95	1.00	0.97
41	0.93	0.93	1.00	0.95
51	0.91	0.91	1.00	0.94
61	0.90	0.90	1.00	0.93
71	0.88	0.88	1.00	0.92
81	0.86	0.86	1.00	0.90
91	0.85	0.85	1.00	0.90
1901	0.83	0.83	1.00	0.88
11	0.83	0.83	1.00	0.88
21	0.68	0.68	1.00	0.80
31	0.83	0.83	1.00	0.88
41	0.83	0.83	1.05	0.90
51	0.83	0.83	1.32	0.92
61	0.68	0.68	1.20	0.83
71	0.83	0.83	1.05	0.84

11.3.3 Comparing the time-path of the Basic Image with the trend of Population changes

By plotting the values of the two indicators – presented in Tables 11.15 and 11.20 respectively – I can draw the time-path for the Basic Image of Coventry over the period 1801-1971 (Figure 11.5). The presence and the positions of three cusps in Figure 11.5 have already been discussed in the previous section; Table 11.21 gives the population of Coventry for the period 1801-1971. Table 11.22 shows

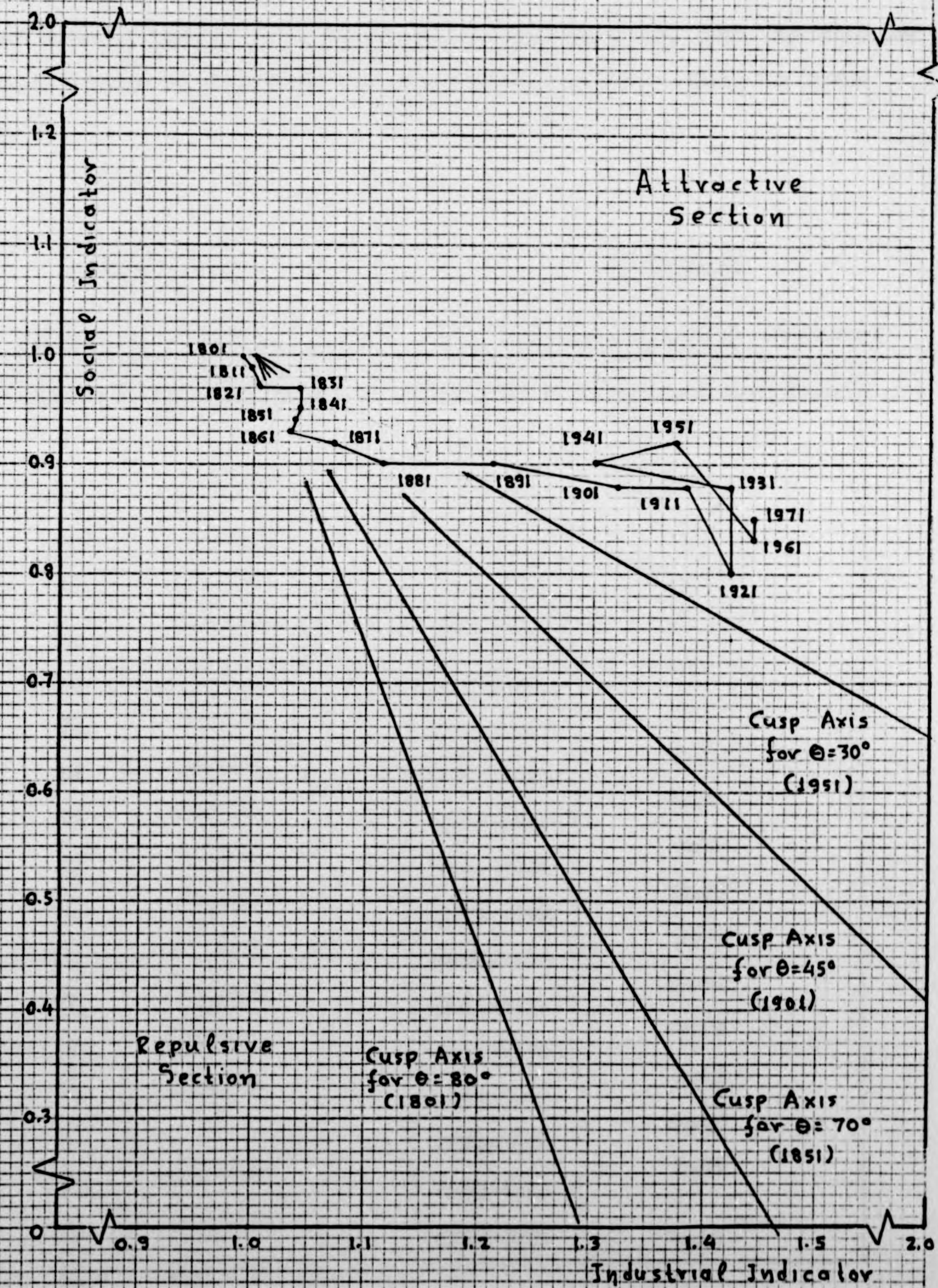

Figure 11.5 Time-Path for Coventry's Basic Image

the rate of population changes due to migration only over the same period. Figure 11.6 illustrates graphically the trend shown in Table 11.22.

TABLE 11.21

POPULATION (Coventry)

Year	Population
1801	16,000
11	18,000
21	21,000
31	27,000
41	31,000
51	36,000
61	41,000
71	38,000
81	45,000
91	59,000
1901	72,000
11	106,000
21	148,000
31	178,000
41	
51	258,000
61	316,000
71	334,000

TABLE 11.22

POPULATION CHANGES (Coventry)

Time Period	Rate of Population changes due to Migration only
1801-1811	-0.16
1811-1821	-0.12
1821-1831	1.06
1831-1841	0.03
1841-1851	0.31
1851-1861	0.18
1861-1871	-2.01
1871-1881	-0.34
1881-1891	0.54
1891-1901	0.57
1901-1911	3.20
1911-1921	1.41
1921-1931	0.69
1931-1941	1.43
1941-1951	1.40
1951-1961	1.20
1961-1971	0.30

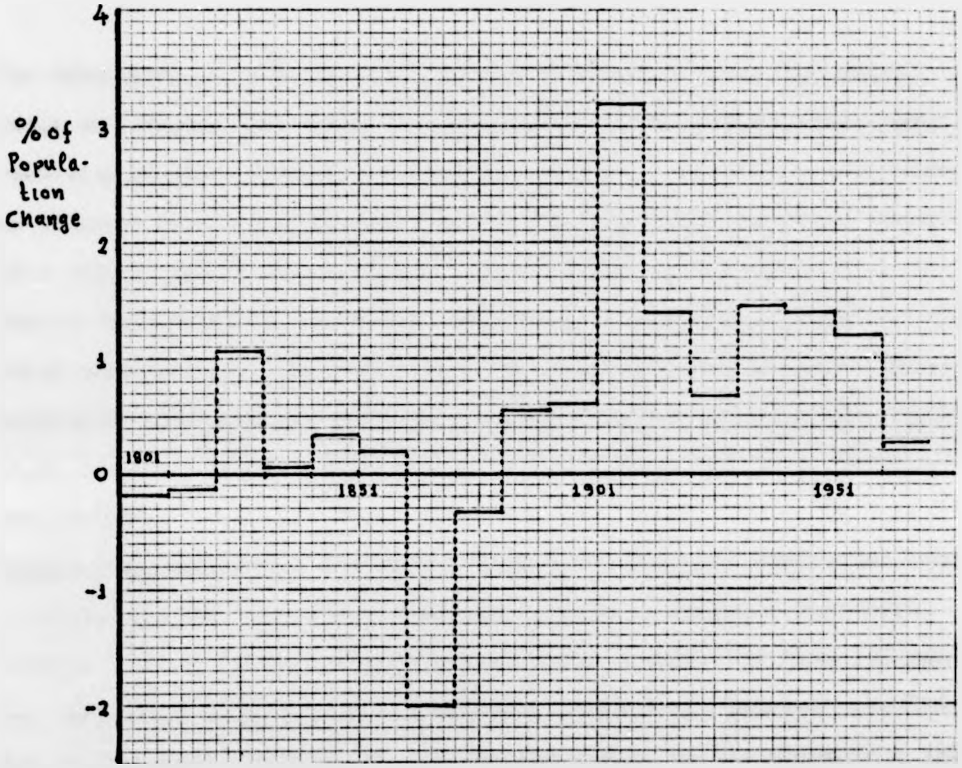

Figure 11.6 Rate of population changes due to migration

Comparing the two graphs shown in Figures 11.5 and 11.6 respectively the following conclusions may be drawn .

Period 1800-1860 (Moderate Industrial Indicator, Moderate Social Indicator – Hypothesis 4): For the period 1800-1860 both graphs lead to similar conclusions. The time-path crosses the cusp around 1810 while Figure 11.6 shows a small jump from low net out-migration to low net in-migration. For the remaining part of the period the time-path indicates a near-normal attractiveness for the city while Figure 11.6 shows a continuous although low net in-migration.

Period 1860-1880 (Moderate Industrial Indicator, Moderate Social Indicator – Hypothesis 4): The period 1860-1880 is a rather special one.

The time-path as drawn for that period does not contain any sudden jumps but Figure 11.6 shows a net out-migration. However, this apparent disagreement between the two graphs can be reasonably explained as follows. The net out-migration between 1860-1880 was not a result of a sudden decline in Coventry's Basic Image but a result of an external factor namely the sudden abolition of all import duties on foreign ribbons. The fact that the Basic Image of Coventry never became Repulsive (although it came very near to it as we can see from Figure 11.5) led to a rapid stabilization and a quick return to a period of prosperity.

Period 1880-1970 (High Industrial Indicator, Moderate Social Indicator = Hypothesis 2): The period 1880-1970 reveals a complete agreement between the two graphs. The time-path never crosses the cusp (although the cusp keeps moving from its original position 1, through positions 2,3 to its final position 4) and remains always on the Attractive Section of the graph. Similarly, Figure 11.6, shows a continuous net in-migration of population during that period. For the last 10-15 years both graphs indicate a slow-down in the city's growth.

Summarising the comparisons of the two graphs I can say that as in the case of Oldham they have shown a remarkable degree of agreement and hence they may be considered as qualitatively equivalent.

11.4 CONCLUSIONS

This Chapter was devoted to the testing of the hypotheses behind the derivation of the graph of Basic Image. Data from two cities, Oldham and Coventry, was used for testing those hypotheses and the results obtained in each case seem to verify them. Although verification of my assumptions for only two cities does not constitute a proof for them the fact that Oldham and Coventry can be considered as the representatives of two large families of cities, including many major industrial cities of this country, gives my results, a much greater significance. It would therefore be fair to claim that the conclusions drawn from my tests may be considered as a strong positive indication that the four sociological hypotheses are indeed true; hence the idea of using the concept of Basic Image as the basis of a model to describe urban development is meaningful and justifiable.

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Chapter 12

Testing the Descriptive Power of the Model

12.1 INTRODUCTION

The last Chapter was devoted to the justification of the use of the concept of Basic Image in modelling urban development. Chapter 12, tests the descriptive power of the proposed model which has been built upon the concepts of Basic and Specific Image. The same two cities, Coventry and Oldham have been chosen as test beds, for the reasons already given in the previous Chapter. The test covers a period of 170 years (1801-1971) and the trend of the development for each city, obtained through the model, is compared to its actual growth. My primary interest, however, lies in its relative development as compared to that of the normal city. Variables expressing selected aspects of the normal city's development are given exogenously, and so are variables expressing national and local trends. In addition, the model requires the exogenous provision of initial values for all its level variables. Figure 12.1, shown already in Chapter 11 but reproduced here to facilitate the presentation, illustrates graphically the objective of Chapter 12.

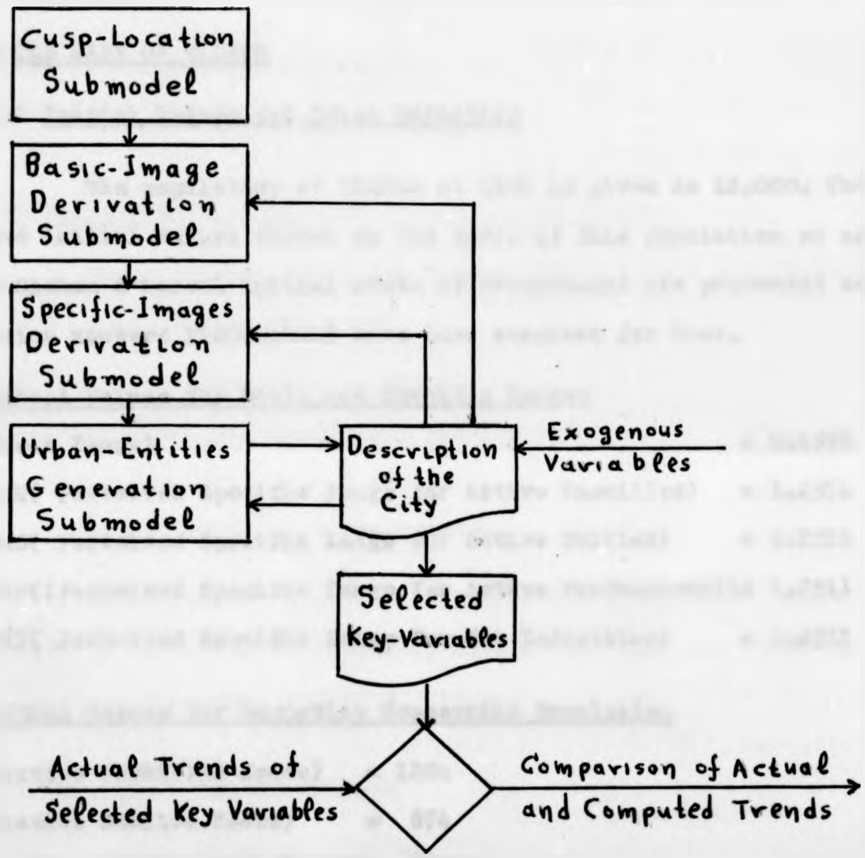

__Figure 12.1__

Objective of Chapter 12

The population of each city at 1801 is given in the relevant population census but no information for the values of its level variables at that time is available. For the purposes of the model the actual population of each city is used; initial values for its level variables are chosen on the basis of the analysis presented in Chapter 3 and Appendix 2 so as to give the city under study a normal initial state of development.

12.2 THE CASE OF OLDHAM

12.2.1 Initial Values for Level Variables

The population of Oldham at 1801 is given as 12,000. The required initial values chosen on the basis of this population so as to give Oldham a normal initial state of development are presented below. Equation numbers 11000-11018 have been reserved for them.

1. Initial Values for Basic and Specific Images

BI(Basic Image) = 0.4768

PSPIAU(Perceived Specific Image for Active Unskilled) = 1.2511

PSPIAS(Perceived Specific Image for Active Skilled) = 1.2511

PSPIAP((Perceived Specific Image for Active Professional)= 1.2511

PSPINI(Perceived Specific Image for New Industries) = 1.2511

2. Initial Values for Variables Concerning Population

AUH(Active Unskilled Heads) = 1204

ASH(Active Skilled Heads) = 874

APH(Active Professional Heads)= 164

RH(Retired Heads) = 320

3. Initial Values for Variables Concerning Industrial Activity

NIU(New Industrial Units) = 247

MIU(Mature Industrial Units) = 247

DIU(Declining Industrial Units) = 0

CJ(Construction Jobs) = 343

FIB(Fit Industrial Buildings) = 505

UFIB(Unfit Industrial Buildings)= 0

4. Initial Values for Variables Concerning Residential Activity

LCHU(Low-Cost Housing Units) = 1166

MCHU(Medium-Cost Housing Units)= 874

HCHU(High-Cost Housing Units) = 164

UFHU(Unfit Housing Units) = 0

12.2.2 Values for Variables Expressing Local Trends

The following variables express local trends and their values must be given exogenously:

RACSIX (Relative Accessibility Index)

RUPDR (Relative Urban Population Density Ratio)

LURF (Land-Use Regulation Factor)

RRGUN (Relative Regional Unemployment)

The values of the four variables for the city of Oldham have been given in Tables 11.1-11.3 of the last chapter. Equations 11400-11409 have been reserved for them.

12.2.3 Discussion of the Results

This section presents the results obtained by applying the model for the case of Oldham and compares them with available data whenever this is possible. Tables and graphs expressing model results are denoted by M.R. while those expressing actual data are denoted by A.D. The obtained results cover the following major aspects of the city's development:

Basic and Specific Images.

Population.

Workforce.

Industrial Activity.

Residential Activity.

In each case both level variables expressing the trend of urban entities in absolute terms and rates (or normalised variables — expressing the relation between the trend of a given entity and the corresponding normal trend— are discussed. My primary interest as I have mentioned already lies in the case of rates.

Basic and Specific Images

Table 12.1 gives the values of the two indicators (II,SI) as well as the value of the Basic Image (BI) for the city of Oldham over the period 1801-1971. The Basic Image "breaks" around 1895 marking the beginning of a period of decline (Figure 12.2). At the time of the break the Industrial Indicator is considerably higher than normal but the value of the Social Indicator has reached a low level. Following the break, the Basic Image goes through a period of further decline succeeded by a period of slight recovery. The recovery is due to an improvement of the Social Indicator for two reasons: (i) decrease of population and relief of overcrowding (ii) limitation of industrial activity and reduction in the number of potential sources of pollution. Around 1945 the situation is very similar to that of 1900; Industrial Indicator higher than normal but low Social Indicator. The model shows a slight fall in the Basic Image over the period 1950-1970. This is probably an underestimation of the real value justified by the fact that no Government measures for the improvement of the depressed areas have been modelled apart from the Rate Equalisation Grant. In general the trend of the Basic Image as obtained by the model agrees with the history of the city as presented in the previous Chapter.

The Specific Images for the various groups of movers (Table 12.2) follow the trend of the Basic Image delayed by the respective perception times. As expected the Specific Image for New Industries responds faster followed by those for Professional and Skilled employees. Unskilled employees require a longer time to perceive any changes and their Image is the last to respond.

TABLE 12.1 (M.R.)

BASIC IMAGE (Oldham)

Year	II	SI	BI
1801	1.364	0.999	0.477
1811	1.380	0.968	0.602
1821	1.396	0.931	0.620
1831	1.420	0.913	0.640
1841	1.442	0.874	0.659
1851	1.479	0.848	0.683
1861	1.515	0.741	0.719
1871	1.431	0.721	0.685
1881	1.325	0.709	0.614
1891	1.222	0.686	0.490
1901	1.108	0.666	-0.624
1911	1.086	0.619	-0.659
1921	1.160	0.507	-0.665
1931	1.132	0.583	-0.699
1941	1.114	0.632	-0.648
1951	1.132	0.569	-0.651
1961	1.096	0.574	-0.689
1971	1.096	0.554	-0.673

KEY

II: Industrial Indicator

SI: Social Indicator

BI: Basic Image

TABLE 12.2 (M.R.)

SPECIFIC IMAGES (Oldham)

Year	PSPIAU	PSPIAS	PSPIAP	PSPINI
1801	1.251	1.251	1.251	1.251
1811	1.290	1.297	1.302	1.306
1821	1.317	1.320	1.321	1.319
1831	1.339	1.337	1.338	1.332
1841	1.359	1.352	1.352	1.344
1851	1.378	1.366	1.366	1.357
1861	1.402	1.385	1.386	1.375
1871	1.415	1.390	1.387	1.375
1881	1.407	1.376	1.370	1.358
1891	1.379	1.340	1.332	1.323
1901	0.881	0.787	0.721	0.718
1911	0.690	0.658	0.661	0.673
1921	0.650	o.624	0.636	0.657
1931	0.599	0.581	0.591	0.619
1941	0.594	0.586	0.593	0.635
1951	0.581	0.576	0.581	0.636
1961	0.549	0.546	0.552	0.628
1971	0.531	0.530	0.536	0.637

KEY

PSPIAU: Perceived Specific Image for Active Unskilled

PSPIAS: Perceived Specific Image for Active Skilled

PSPIAP: Perceived Specific Image for Active Professionals

PSPINI: Perceived Specific Image for New Industries

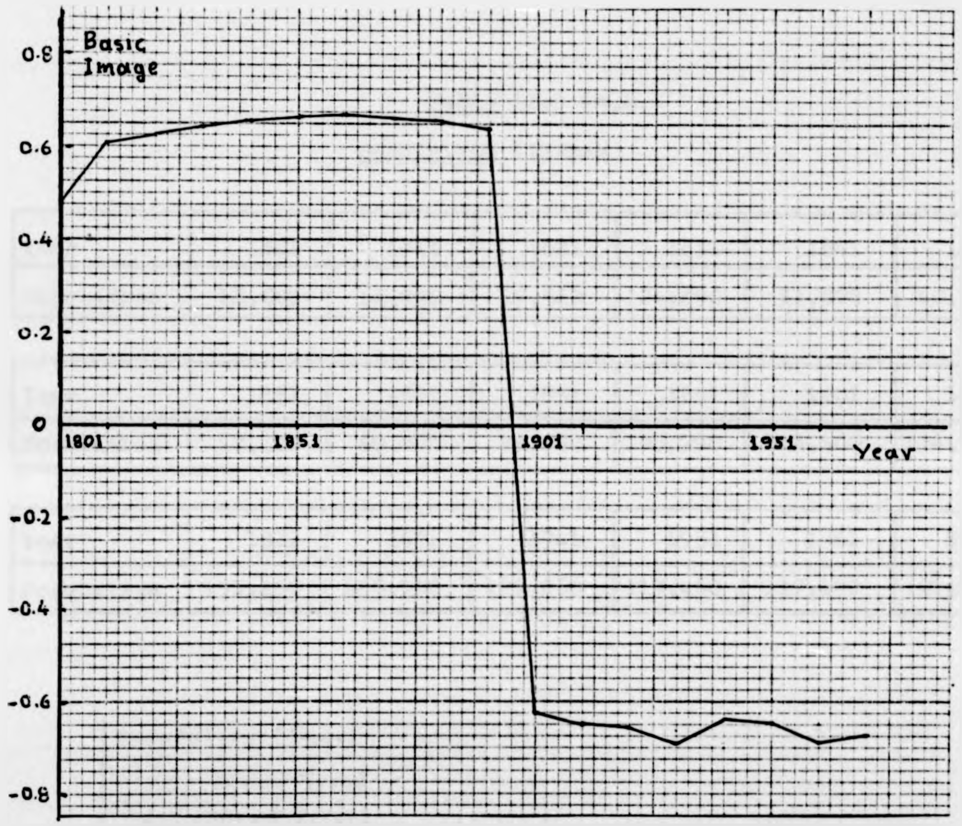

Figure 12.2 Basic Image (Oldham)

Population

Table 12.3 presents the trend of population changes as obtained by the model. Figure 12.2 illustrates graphically the population trend shown in Table 12.3 and the actual trend of population growth. The hypothetical trend that would have been obtained had the city developed under normal conditions is also shown. The model output seems to follow the real trend closely, much closer than the "normal" output does. The observed underestimation may be attributed to the fact that certain secondary local factors which speeded up the growth during the early stages of the city's development have not

TABLE 12.3 (M.R.)

POPULATION (Oldham)

Year	1801	1811	1821	1831	1841	1851
Population	12,000	14,990	19,520	24,890	31,870	40,270
Year	1861	1871	1881	1891	1901	1911
Population	47,100	60,500	79,780	105,790	123,400	134,550
Year	1921	1931	1941	1951	1961	1971
Population	131,150	125,150	121,260	119,460	117,490	101,090

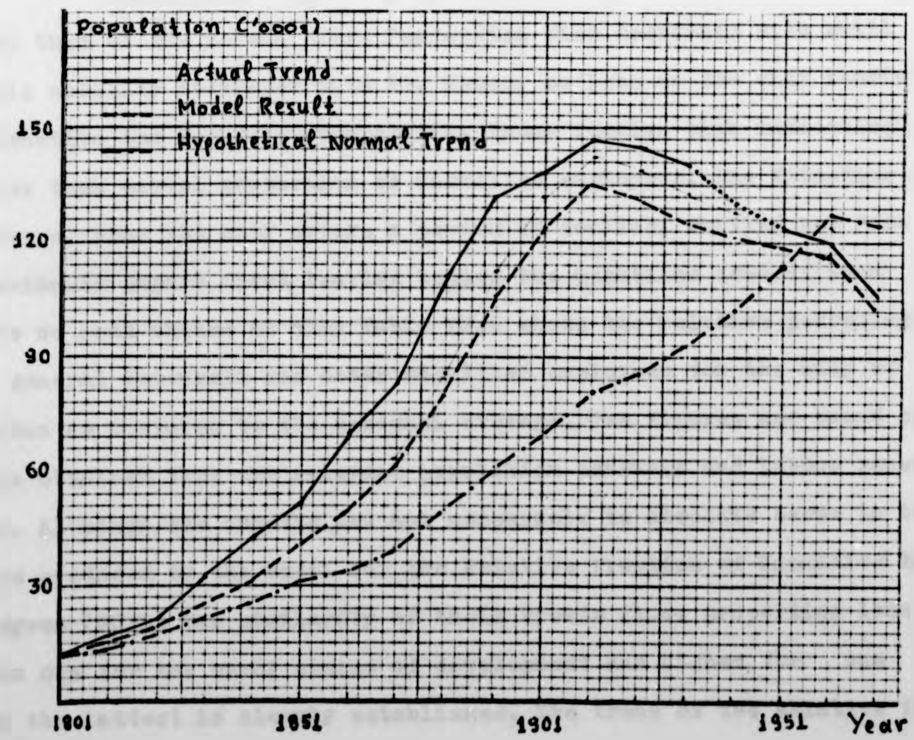

Figure 12.3 Population (Oldham)

been modelled. Such factors include the presence of water resources, the suitability of the area's climate for cotton spinning the availability of labour free from guild restrictions and certain characteristics for the area's vital statistics. For further discussion on the subject of secondary local factors see section 12.6.

Workforce

Table 12.4 gives the number of Retired Heads and the number of Active Heads in the various occupational groups. Directly comparable data for those quantities is not available because the model uses a fixed grouping method while the relevant census classifications have changed many times over the period covered by the model. However an attempt at a rough comparison is made below where the relevant rates are discussed.

Table 12.5 compares the composition of Oldham's workforce with that of the normal city. Perception time decreases with skill while mobility increases with it. Hence, as long as the city remains attractive the Workforce Composition Index remains high indicating a lower than normal proportion of unskilled employees. The situation is reversed when the city enters a period of decline. Skilled and Professionals depart first leaving behind the unskilled some of whom have no real choice at all. Table 12.6 shows the relative percentage of general labourers and other unskilled employees for the city of Oldham as compared to the national average. The figures are based on data obtained from the relevant population censuses and labour gazettes. Although the results are not comparable in absolute terms to the ones produced by the model for the Relative Fraction of Unskilled Employees (RUFR) the similarity of their trends (i.e. proportion less than one for the early stages of development and higher for one for the latter) is clearly established. The trend of the Relative Pro-

TABLE 12.4 (M.R.)

LEVELS CONCERNING WORKFORCE (Oldham)

Year	AUH	ASH	APH	RH
1801	1,204	874	163	319
1811	1,464	1,089	209	379
1821	1,856	1,416	275	483
1831	2,357	1,844	363	619
1841	2,917	2,339	465	837
1851	3,594	2,951	594	1,104
1861	4,525	3,803	774	1,427
1871	5,698	4,894	1,006	1,748
1881	7,250	6,359	1,335	2,181
1891	9,186	8,211	1,757	2,843
1901	10,932	9,837	2,129	3,648
1911	12,275	10,628	2,331	4,573
1921	12,860	10,641	2,401	5,413
1931	13,559	10,691	2,471	6,477
1941	13,714	10,541	2,741	7,592
1951	13,967	10,486	3,046	8,874
1961	13,855	10,029	3,080	9,482
1971	12,733	8,886	2,916	9,494

KEY

AUH: Active Unskilled Heads

ASH: Active Skilled Heads

APH: Active Professional Heads

RH : Retired Heads

TABLE 12.4 (M.R.)

LEVELS CONCERNING WORKFORCE (Oldham)

Year	AUH	ASH	APH	RH
1801	1,204	874	163	319
1811	1,464	1,089	209	379
1821	1,856	1,416	275	483
1831	2,357	1,844	363	619
1841	2,917	2,339	465	837
1851	3,594	2,951	594	1,104
1861	4,525	3,803	774	1,427
1871	5,698	4,894	1,006	1,748
1881	7,250	6,359	1,335	2,181
1891	9,186	8,211	1,757	2,843
1901	10,932	9,837	2,129	3,648
1911	12,275	10,628	2,331	4,573
1921	12,860	10,641	2,401	5,413
1931	13,559	10,691	2,471	6,477
1941	13,714	10,541	2,741	7,592
1951	13,967	10,486	3,046	8,874
1961	13,855	10,029	3,080	9,482
1971	12,733	8,886	2,916	9,494

KEY

AUH: Active Unskilled Heads

ASH: Active Skilled Heads

APH: Active Professional Heads

RH : Retired Heads

TABLE 12.5 (M.R.)

RATES CONCERNING WORKFORCE (Oldham)

Year	RUFR	RSFR	RPFR	RWCPIX
1801	1.000	1.000	1.000	1.000
1811	0.990	1.011	1.012	1.011
1821	0.979	1.024	1.025	1.024
1831	0.968	1.036	1.038	1.036
1841	0.958	1.048	1.049	1.048
1851	0.947	1.060	1.060	1.060
1861	0.937	1.071	1.071	1.071
1871	0.928	1.082	1.081	1.082
1881	0.919	1.091	1.088	1.090
1891	0.912	1.099	1.093	1.098
1901	0.911	1.102	1.084	1.098
1911	0.931	1.080	1.054	1.074
1921	0.954	1.053	1.036	1.049
1931	0.978	1.026	1.013	1.023
1941	1.001	1.000	0.993	0.999
1951	1.024	0.978	0.970	0.976
1961	1.050	0.954	0.947	0.952
1971	1.079	0.929	0.922	0.927

KEY

RUFR : Relative Unskilled Fraction

RSFR : Relative Skilled Fraction

RPFR : Relative Professional Fraction

RWCPIX: Relative Workforce Composition Index

TABLE 12.6 (A.D.)

GENERAL LABOURERS & OTHER UNSKILLED (Oldham)

Year	Gen. Lab. & Other Unskilled as a proportion of the total workforce		Relative Proportion for Oldham
	Oldham	National Average	
1861	0.83	3.44	0.24
1871	n.a	n.a	n.a
1881	1.75	5.05	0.35
1891	0.91	4.57	0.20
1901	2.67	2.86	0.94
1911	(1.73)	1.81	(0.96)
1921	4.41	4.24	1.04
1931	4.59	4.20	1.10
1941	n.a	n.a	n.a
1951	11.89	6.33	1.87
1961	7.61	5.29	1.45
1971	(7.60)	(5.30)	(1.45)

portion of Professional employees (RPFR) as produced by the model may be an overestimation of the reality at least for the first 100-120 years. The reason is that the model does not distinguish between manufacturing and Service Industrial Sectors. The latter is the main employer of professionals but Oldham has traditionally had a relatively small service sector.

Industrial Activity

Table 12.7 gives the number of industrial units and available jobs as obtained by the model. Classification of industrial units into New, Mature and Declining is only a convenient one used

TABLE 12.7 (M.R.)

LEVELS CONCERNING INDUSTRIAL UNITS & EMPLOYMENT (Oldham)

Year	NIU	MIU	DIU	TIU	TJ
1801	247	247	0	494	5,283
1811	259	279	65	603	6,488
1821	325	318	118	761	8,182
1831	447	380	167	994	10,690
1841	581	474	220	1,275	13,722
1851	788	604	283	1,675	18,025
1861	896	761	361	2,018	21,817
1871	1,252	959	455	2,666	28,741
1881	1,589	1,236	579	3,404	36,696
1891	2,126	1,606	747	4,479	48,153
1901	2,277	2,062	1,041	5,380	56,600
1911	2,632	2,399	1,531	6,562	68,636
1921	1,646	2,431	2,008	6,085	60,883
1931	1,161	2,064	2,343	5,568	56,665
1941	1,361	1,763	2,482	5,606	58,067
1951	1,129	1,569	2,510	5,208	53m527
1961	713	1,260	2,460	4,433	44,922
1971	315	838	2,294	3,447	34,703

KEY

NIU: New Industrial Units

MIU: Mature Industrial Units

DIU: Declinining Industrial Units

TIU: Total Industrial Units

TJ : Total Jobs

for the purposes of the model and no directly comparable data is avai - lable. Nevertheless one could plot the total number of industrial jobs as obtained by the model against the total number of occupied persons in Oldham as given by the relevant censuses after 1861.(Figure 12.4). The fact, however, that the model treats industrial activity in an aggregate way without distinguishing between any particular types of industry would normally limit the validity of a quantitative comparison between the actual and the computed trends. In the present case, the period 1860-1880 is characterised by a large underestimation of the actual trend. This is due to the fact that cotton industry, the basic industry of Oldham for that period, was labour-intensive and occupying a high proportion of female employees (approximately 55% of the total workforce as compared to a national average of about

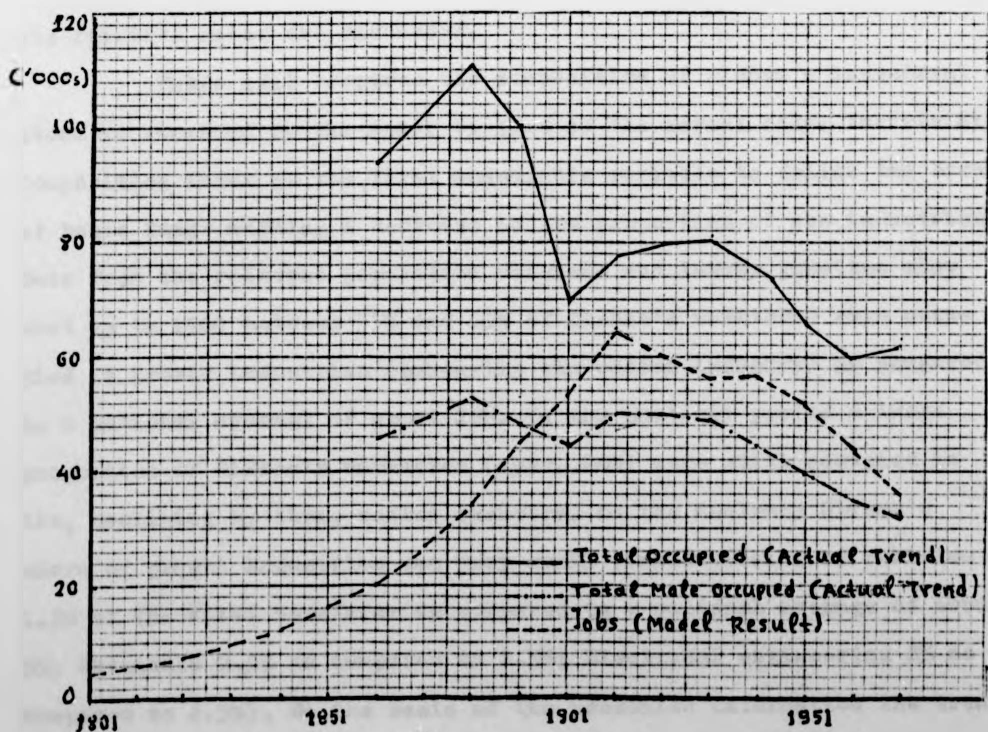

Figure 12.4 Jobs and Total Occupied Persons (Oldham)

30%). This local factor which contributed to an increase of Oldham's workforce has not been included in the working model. Actual data show an absolute decrease of Oldham's workforce for the period 1880-1900 while the computed output continues its increasing trend. This difference is due to the fact that the model assumes a "normal" industrial basis for every city while Oldham at that period was overdependent on a rapidly declining industry. The inclusion in the model of a factor expressing diversification would improve its fit in this and other similar cases. For relevant discussion see section 12.6. Finally, for the latter part of the period covered by the model, which saw a broadening of Oldham's industrial basis and a decrease in the share of female employees to near-normal levels, the qualitative equivalence of the two trends is clearly noted. A better picture of how the model generates industrial activity is given below where the relative rates are discussed.

Table 12.8 compares the composition of Oldham's industrial stock as obtained by the model to that of the normal city. Industrial Composition Index is the first measurable variable to follow the break of Basic Image marking a decrease in the proportion of new industries. Data from the relevant population censuses and labour gazettes show that up to 1900 between 35% and 40% of Oldham's workforce were occupied in growth industries (primarily the cotton industry) as compared to a national average of about 20%. In the post-war period a large proportion of Oldham's workforce (appr. 20%) were still occupied in the, declining by then, cotton industry. On the contrary Oldham's share of growth industries was very small (Manufacturing of vehicles 1.5% of the total workforce as compared to a national average of about 5%; Chemicals 0.3% as compared to 2.5%; Electrical engineering 2% as compared to 2.5%). On the basis of the presented information the trend

TABLE 12.8 (M.R.)

RATES CONCERNING INDUSTRIAL UNITS & EMPLOYMENT (Oldham)

Year	RNIFR	RMIFR	RDIFR	RICPIX	RTJR
1801	1.000	1.000	0.000	1.000	1.001
1811	1.080	0.978	0.834	1.042	0.994
1821	1.139	0.969	0.800	1.077	0.993
1831	1.173	0.962	0.767	1.101	1.003
1841	1.202	0.960	0.739	1.120	1.016
1851	1.218	0.956	0.714	1.132	1.034
1861	1.263	0.962	0.697	1.155	1.050
1871	1.264	0.958	0.975	1.161	1.071
1881	1.271	0.962	0.667	1.166	1.091
1891	1.252	0.966	0.668	1.158	1.116
1901	1.176	1.004	0.750	1.116	1.117
1911	0.986	1.023	0.990	0.997	1.126
1921	0.845	0.986	1.201	0.899	1.083
1931	0.715	0.913	1.393	0.796	1.093
1941	0.670	0.865	1.615	0.735	1.042
1951	0.605	0.810	1.787	0.675	0.957
1961	0.501	0.727	1.928	0.587	0.863
1971	0.347	0.593	2.042	0.455	0.777

KEY

RNIFR : Relative New Industries Fraction

RMIFR : Relative Mature Industries Fraction

RDIFR : Relative Declining Industries Fraction

RICPIX: Relative Industrial Composition Index

RTJR : Relative Total Job Ratio

of the Relative Fraction of New Industries (RNIFR) — as produced by the model— (i.e. fraction higher than 1 in the early stages of Oldham's development and lower than 1 for the latter), seems to fit the historical reality. The same applies for the Relative Fraction of Declining Industries (RDIFR). The last column of Table 12.8 concerns job availability. A value of the Relative Total Job Ratio (RTJR) greater than 1 indicates higher than normal vacancy rates while a value less than 1 indicates job shortage. A complete series of unemployment rates for the city of Oldham is not available and hence the relevant regional rates will be used instead. Even in this case, however, unemployment rates are available for the post-1921 period only (Table 11.3). Although actual data and model output is not directly comparable their relationship may be roughly established. Both the model and the census indicate higher than normal unemployment rates for the post-war period. According to historical facts, however, one would have expected the model to have produced higher than normal unemployment rates from an earlier date. Its apparent failure to do so may be reasonably justified on the grounds of the exclusion from it of factors expressing the lack of industrial diversification in Oldham and the labour-intensive nature of its industries. Once the cotton industry had entered a period of decline those two local factors resulted in a sharp fall in the numaber of available jobs (i.e. a sharp increase in unemployment). Such a sudden change of trend can not be possibly generated by a general model not including the two main local reasons for its occurence. However, the model output adjusts to the new trend after a delay period and follows it closely for the remaining part of the period.

Table 12.9 contains model-output variables concerning industrial infrastructure. As in the case of the industrial unit, industrial

TABLE 12.9 (M.R.)

LEVELS & RATES CONCERNING INDUSTRIAL BUILDINGS (Oldham)

Year	FIB	UFIB	RUFIBF
1801	505	0	0.000
1811	613	7	0.797
1821	769	30	0.770
1831	1,001	68	0.736
1841	1,280	117	0.703
1851	1,680	181	0.668
1861	2,022	262	0.644
1871	2,669	364	0.611
1881	3,406	492	0.586
1891	4,480	654	0.565
1901	5,378	866	0.572
1911	6,556	1,101	0.712
1921	6,080	1,349	0.886
1931	5,560	1,622	1.071
1941	5,599	1,725	1.386
1951	5,201	1,788	1.813
1961	4,472	1,715	2.361
1971	3,716	1,682	2.824

KEY

FIB : Fit Industrial Buildings

UFIB : Unfit Industrial Buildings

RUFIBF: Relative Unfit Industrial Buildings Fraction

building is a convenient entity used for the purposes of the model and no directly comparable data is available. However the last column of Table 12.9 (RUFIBF- Relative Unfit Industrial Buildings Fraction) is indirectly comparable to available data expressing industrial de-rsliction. Local Government returns in 1966 gave the proportion on industrial dereliction for the County of Lancashire as approximately 3 times greater than the national average (Barr[1]). For the same period the model gives the proportion of unfit industrial buildings for the city of Oldham as 2.7 times that of the normal city.

Residential Activity

Table 12.10 gives the number of housing units of every type as obtained by the model. As in the case of industrbes the classification of housing units into High, Medium and Low-Cost is a convenient way used for the purposes of the model. However, the total number of generated housing units is comparable to that given by the census. Figure 12.5 compares the trend of the housing stock level as obtained by

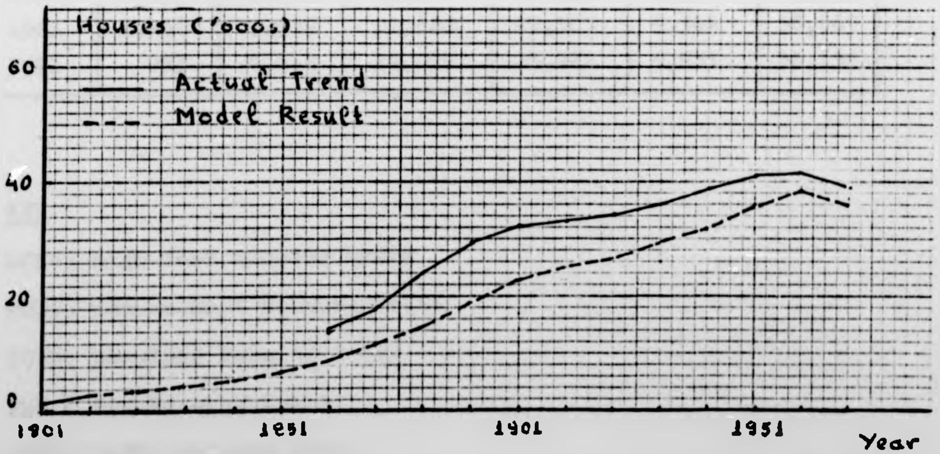

Figure 12.5 Houses (Oldham)

TABLE 12.10 (M.R.)

LEVELS CONCERNING HOUSING UNITS (Oldham)

Year	HCHU	MCHU	LCHU	FHU	UFHU	THU
1801	164	874	1,166	2,204	0	2,204
1811	199	1,058	1,280	2,537	151	2,688
1821	253	1,341	1,500	3,094	343	3,437
1831	337	1,771	1,865	3,973	573	4,546
1841	431	2,248	2,228	4,907	854	5,761
1851	556	2,878	2,722	6,156	1,147	7,303
1861	658	3,224	3,137	7,019	1,532	8,551
1871	859	4,223	3,850	8,932	1,970	10,902
1881	1,163	5,712	4,987	11,862	2,534	14,396
1891	1,550	7,567	6,369	15,486	3,275	18,761
1901	1,833	8,849	7,558	18,240	4,188	22,428
1911	1,875	9,370	9,125	20,370	5,268	25,638
1921	1,632	8,214	10,078	19,654	6,472	26,126
1931	1,555	8,099	12,353	22,007	7,827	29,834
1941	1,484	7,682	14,414	23,580	8,394	31,975
1951	1,625	8,747	16,800	27,172	8,891	36,063
1961	1,266	9,379	18,860	29,505	9,344	38,849
1971	983	8,141	19,097	28,221	9,931	38,152

KEY

HCHU: High-Cost Housing Units

MCHU: Medium-Cost Housing Units

LCHU: Low-Cost Housing Units

FHU : Fit Housing Units

UFHU: Unfit Housing Units

THU : Total Housing Units

the model to that given by the relevant official statistics. The model's output follows closely the real trend. The observed underestimation is proportional to that shown in the case of population.

Table 12.11 contains information concerning the quality and availability of Oldham's stock as compared to the housing stock of the normal city. The Relative Housing Quality Index (RHQLIX) follows the trend of the Basic Image indicating a lowering in the housing standards once the city has entered a period of decline. Local Government returns in 1966 gave the proportion of unfit houses in Oldham as approximately 2 times higher than the national average. For the same period the model gives a proportion (UFHFR) of 1.7 times higher than the normal one. The last column of Table 12.11 gives the ratio of families over the available housing units. The nearest available data is the number of persons per room as given by the census for the period 1911-1971 (Table 11.5). The similarity in the trend between the real data and the model's results is clearly shown.

TABLE 12.11 (M.R.)

RATES CONCERNING HOUSING UNITS (Oldham)

Year	RUFHFR	RHQLIX	RFHR
1801	0.000	1.000	1.000
1811	1.022	1.002	1.011
1821	1.054	1.002	1.021
1831	1.046	1.007	1.023
1841	1.040	1.010	1.030
1851	0.988	1.024	1.022
1861	0.961	1.028	1.028
1871	0.898	1.054	1.066
1881	0.884	1.065	1.066
1891	0.879	1.071	1.071
1901	0.895	1.059	1.077
1911	1.050	0.993	1.114
1921	1.210	0.915	1.125
1931	1.367	0.847	1.102
1941	1.506	0.795	1.105
1951	1.546	0.794	1.027
1961	1.660	0.772	1.012
1971	1.722	0.749	0.978

KEY

RUFHFR: Relative Unfit Housing Fraction

RHQLIX: Relative Housing Quality Index

RFHR : Relative Fit Housing Ratio

12.3 THE CASE OF COVENTRY

12.3.1 Initial Values for Level Variables

The population of Coventry at 1800 is given as 16,000. The following equations (numbers 11000-11018 reserved for them) express the reqaired initial values.

1. Initial Values for Basic and Specific Images

BI(Basic Image)	= 0
PSPIAU(Perceived Specific Image for Active Unskilled)	= 1
PSPIAS(Perceived Specific Image for Active Skilled)	= 1
PSPIAP(Perceived Specific Image for Active Professional)	= 1
PSPINI(Perceived Specific Image for New Industries)	= 1

2. Initial Values for Variables Concerning Population

AUH(Active Unskilled Heads)	= 1605
ASH(Active Skilled Heads)	= 1165
APH(Active Professional Heads)	= 218
RH(Retired Heads)	= 426

3. Initial Values for Variables Concerning Industrial Activity

NIU(New Industrial Units)	= 329
MIU(Mature Industrial Units)	= 329
DIU(Declining Industrial Units)	= 0
CJ(Construction Jobs)	= 457
FIB(Fit Industrial Buildings)	= 673
UFIB(Unfit Industrial Buildings)	= 0

4. Initial Values for Variables Concerning Residential Activity

LCHU(Low-Cost Housing Units)	= 1555
MCHU(Medium-Cost Housing Units)	= 1165
HCHU(High-Cost Housing Units)	= 218
UFHU(Unfit Housing Units)	= 0

12.3.2 Values for Variables Expressing Local Trends

The following variables express local trends and their values must be given exogenously:

RACSIX (Relative Accessibility Index)

RUPDR (Relative Urban Population Density Ratio)

LURF (Land-Use Regulation Factor)

RRGUN (Relative Regional Unemployment)

The values of the four variables for the city of Coventry have been given in Tables 11.12-11.14 of the last chapter. Equations 11400-11409 have been reserved for them.

12.3.3 Discussion of the Results

The following Tables summarise the results obtained through the model when it is applied in the case of Coventry. As in the previous case the results cover the same 5 major aspects of Coventry's development; both level variables — expressing its development in absolute terms — and rates — expressing its development as compared to that of the normal city — are discussed.

Basic and Specific Images

Table 12.12 gives the values of Coventry's Industrial and Social Indicators and also the value of its Basic Image over the period 1801-1971. Unlike the case of Oldham there is no decisive jump in Coventry's Basic Image. It remains around the normal value for the period 1800-1870 and then it enters a period of continuous increase (1870-1940). The fast city growth reduces the value of its Social Indicator which however is not reaching the low levels experienced by Oldham; instead it is stabilised and even increases in the latter part of the period. The last 20-30 years display a slight decrease in the Basic Image which nevertheless remains always attractive. The

TABLE 12.12 (M.R.)

BASIC IMAGE (Coventry)

Year	II	SI	BI
1801	0.991	0.998	0.000
1811	0.999	0.996	-0.122
1821	1.007	0.994	0.140
1831	1.039	0.997	0.271
1841	1.040	0.989	0.282
1851	1.035	0.979	0.265
1861	1.029	0.943	0.199
1871	1.074	0.924	0.324
1881	1.107	0.917	0.380
1891	1.212	0.902	0.503
1901	1.318	0.857	0.602
1911	1.377	0.830	0.626
1921	1.423	0.735	0.606
1931	1.416	0.808	0.605
1941	1.296	0.918	0.605
1951	1.367	0.850	0.479
1961	1.422	0.807	0.502
1971	1.422	0.767	0.487

KEY

II: Industrial Indicator

SI: Social Indicator

BI: Basic Image

Social Indicator is probably overestimated for the period 1940-1960 because the severe damages suffered by Coventry during the Second World War have not been modelled. In general however, the trend of the Basic Image as generated by the model agrees with the history of the city as presented in the previous chapter.(Figure 12.6).

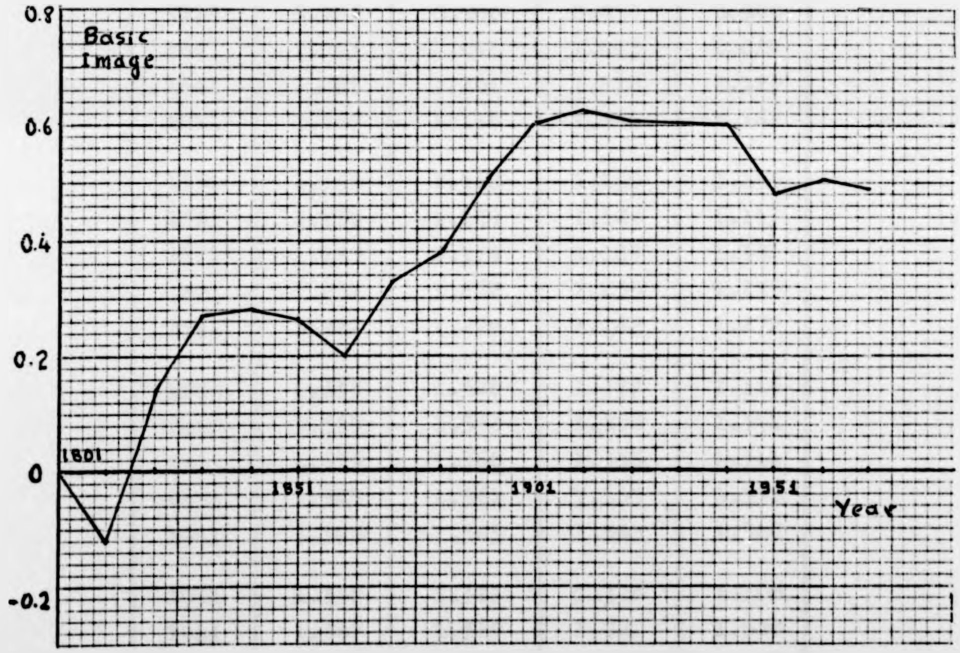

Figure 12.6 **Basic Image (Coventry)**

The Specific Images as perceived by the various groups of movers (Table 12.13) follow the trend of the Basic Image delayed by the respective perception times. Relevant comments made in the case of Oldham are valid in this case also.

TABLE 12.13 (M.R.)

SPECIFIC IMAGES (Coventry)

Year	PSPIAU	PSPIAS	PSPIAP	PSPINI
1801	1.000	1.000	1.000	1.000
1811	0.965	0.960	0.955	0.960
1821	1.003	1.011	1.025	1.029
1831	1.085	1.101	1.118	1.120
1841	1.147	1.158	1.164	1.162
1851	1.160	1.162	1.160	1.155
1861	1.136	1.129	1.120	1.113
1871	1.175	1.179	1.189	1.181
1881	1.231	1.232	1.235	1.225
1891	1.282	1.279	1.282	1.272
1901	1.335	1.328	1.327	1.316
1911	1.369	1.353	1.350	1.344
1921	1.379	1.360	1.353	1.341
1931	1.383	1.361	1.355	1.335
1941	1.395	1.365	1.363	1.348
1951	1.358	1.321	1.318	1.306
1961	1.367	1.329	1.324	1.308
1971	1.363	1.323	1.316	1.292

KEY

PSPIAU: Perceived Specific Image for Active Unskilled

PSPIAS: Perceived Specific Image for Active Skilled

PSPIAP: Perceived Specific Image for Active Professionals

PSPINI: Perceived Specific Image for New Industries

Population

Table 12.14 presents the trend of population changes as obtained by the model. Figure 12.7 illustrates graphically the population trend shown in Table 12.14 together with the actual trend of population growth. The hypothetical trend which would have been produced had the city developed under normal conditions is also shown. As in the case of Oldham the model's output seems to follow the real trend closely , closer than the normal output does. The observed overestimation during the period 1860-1900 is due to the collapse of ribbon industry and the subsequent outflow of many ribbon workers. Although in trouble for some time the ribbon industry collapsed when

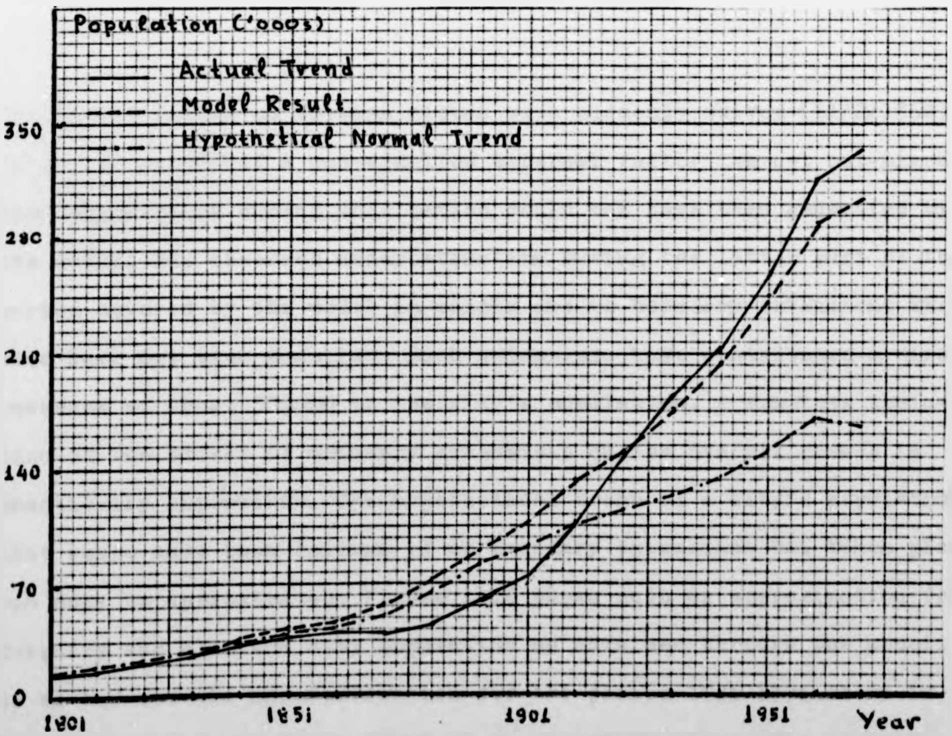

Figure 12.7 Popualtion (Coventry)

TABLE 12.14 (M.R.)

POPULATION (Coventry)

Year	1801	1811	1821	1831	1841	1851
Population	16,000	19,230	23,900	29,040	35,520	42,840
Year	1861	1871	1881	1891	1901	1911
Population	47,530	57,410	71,890	92,000	108,510	133,490
Year	1921	1931	1941	1951	1961	1971
Popualtion	152,870	175,170	205,770	244,580	290,630	302,380

the import duties on foreign ribbon were suddenly waived (11/2/1860). Being the result of a non-modelled external factor the net out-migration experienced during this period could not have been generated by the model. The observed underestimation during the latter part of the period covered by the model is mainly due to boundary extensions which also have not been modelled. Such extensions have contributed a direct increase of about 50,000 to the city's population. A complete isolation of the effect of boundary extensions on the overall growth is practically impossible. The hypothetical trend of a city's population that would have been followed if no boundary extensions had taken place can only be approximated. Figure 12.8 shows such an approximation for Coventry and also the city population as obtained through the model. As we can see the underestimation for the period 1921-1971 shown in Figure 12.7 has now given place to an overestimation; this is only a natural consequence of the overestimation during the period 1860-1880 which has been discussed already.

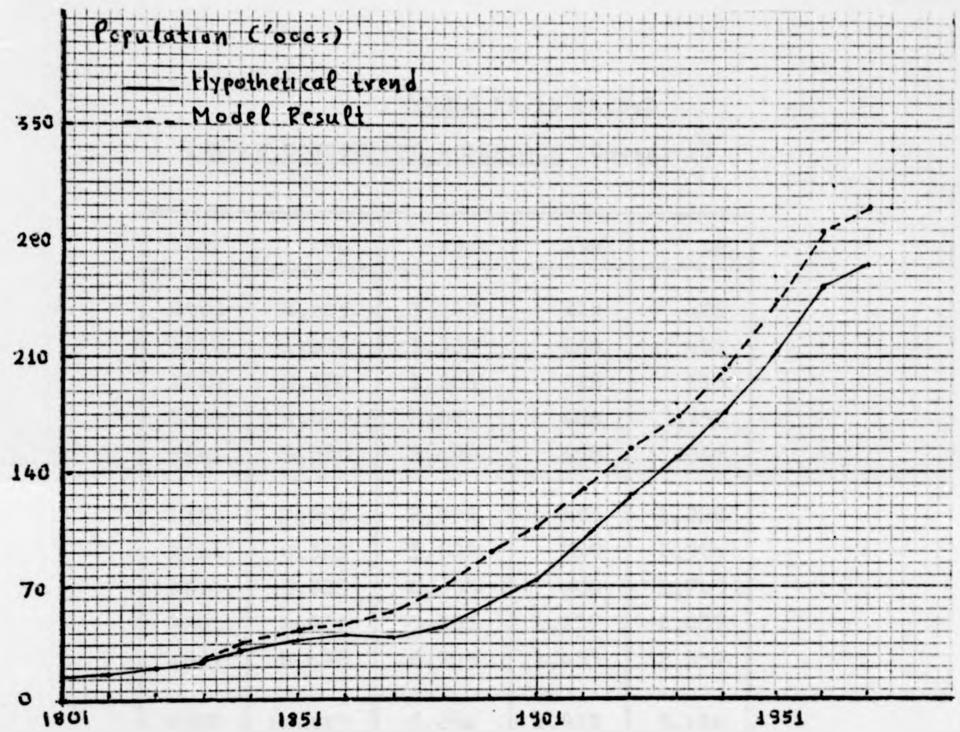

Figure 12.8 Population (Coventry) when boundary changes are taken into account.

Workforce

Table 12.15 gives the number of Retired Heads and the number of Active Heads in the various occupational groups. Table 12.16 compares the composition of Coventry's workforce as obtained by the model to that of the normal city. As in the case of Oldham the qualitative equivalence of trends for the Relative Fraction of Unskilled Employees (RUFR) produced by the model and the relative percentage of general labourers and other unskilled employees as given by the census (Table 12.17) is clearly noted. Comments concerning the Relative Fraction of Professionals (RPFR) which were made for the case of Oldham apply for the case of Coventry as well.

TABLE 12.15 (M.R.)

LEVELS CONCERNING WORKFORCE (Coventry)

Year	AUH	ASH	APH	RH
1801	1,605	1,165	218	426
1811	1,896	1,380	264	498
1821	2,320	1,688	328	613
1831	2,837	2,071	408	751
1841	3,380	2,490	498	967
1851	3,997	2,981	603	1,220
1861	4,803	3,621	740	1,504
1871	5,725	4,355	900	1,745
1881	6,933	5,368	1,137	2,057
1891	8,476	6,705	1,453	2,557
1901	10,117	8,204	1,817	3,196
1911	12,451	10,349	2,340	4,186
1921	14,864	12,656	2,915	5,538
1931	18,247	15,898	3,726	7,711
1941	21,691	19,731	5,172	10,754
1951	25,816	24,523	7,173	15,054
1961	29,976	29,336	9,061	19,173
1971	32,236	32,684	10,774	22,956

KEY

AUH: Active Unskilled Heads

ASH: Active Skilled Heads

APH: Active Professional Heads

RH : Retired Heads

TABLE 12.16 (M.R.)

RATES CONCERNING WORKFORCE (Coventry)

Year	RUFR	RSFR	RPFR	RWCPIX
1801	1.000	1.000	1.000	1.000
1811	1.001	0.999	0.999	0.999
1821	1.002	0.998	0.998	0.998
1831	1.001	0.999	1.001	1.000
1841	0.997	1.003	1.008	1.004
1851	0.992	1.008	1.014	1.010
1861	0.988	1.013	1.018	1.014
1871	0.984	1.017	1.022	1.018
1881	0.977	1.024	1.031	1.026
1891	0.969	1.034	1.041	1.035
1901	0.958	1.045	1.052	1.046
1911	0.948	1.057	1.063	1.057
1921	0.938	1.066	1.071	1.067
1931	0.929	1.076	1.078	1.077
1941	0.917	1.086	1.085	1.086
1951	0.905	1.093	1.092	1.093
1961	0.896	1.100	1.099	1.100
1971	0.885	1.107	1.104	1.106

KEY

RUFR : Relative Unskilled Fraction

RSFR : Relative Skilled Fraction

RPFR : Relative Professional Fraction

RWCPIX: Relative Workforce Composition Index

TABLE 12.17 (A.D.)

Year	Gen. Lab. & Other Unskilled as a proportion of the total workforce		Relative Proportion for Coventry
	Coventry	National Average	
1861	1.37	3.44	0.40
1871	n.a	n.a	n.a
1881	(1.52)	5.05	0.30
1891	1.34	4.57	0.30
1901	1.24	2.86	0.43
1911	1.06	1.81	0.59
1921	3.65	4.24	0.86
1931	4.03	4.20	0.95
1941	n.a	n.a	n.a
1951	6.02	6.33	0.94
1961	4.77	5.29	0.90
1971	(4.70)	(5.30)	(0.90)

Industrial Activity

Table 12.18 gives the number of industrial units and available jobs as obtained by the model. Although no directly comparable data is avilable one could plot the total number of industrial jobs as obtained by the model against the total number of occupied persons in Coventry as given by the census after 1860 (Figure 12.9). The period 1860-1880 is characterised by an underestimation of the actual trend. The reasons given for the case of Oldham apply in this case as well. The remaining period shows a close fit of the model results to the real data.

Table 12.19 compares the composition of Coventry's industrial stock to that of the normal city. Data from the relevant popula-

TABLE 12.18 (M.R.)

LEVELS CONCERNING INDUSTRIAL UNITS & EMPLOYMENT (Coventry)

Year	NIU	MIU	DIU	TIU	TJ
1801	329	329	0	658	7,037
1811	310	372	102	784	8,366
1821	352	406	185	943	10,076
1831	452	459	251	1,162	12,428
1841	558	538	311	1,407	15,064
1851	719	647	377	1,743	18,656
1861	755	770	458	1,902	20,431
1871	982	910	549	2,441	26,137
1881	1,190	1,094	648	2,932	31,443
1891	1,567	1,337	765	3,669	39,367
1901	1,842	1,637	908	4,387	47,205
1911	2,899	2,087	1,084	6,070	65,152
1921	2,631	2,588	1,331	6,550	71,104
1931	2,773	2,945	1,610	7,328	79,434
1941	4,496	3,525	1,905	9,926	106,778
1951	5,461	4,489	2,317	12,267	131,810
1961	5,614	5,430	2,854	13,899	149,937
1971	4,962	6,057	3,441	14,460	157,175

KEY

NIU: New Industrial Units

MIU: Mature Industrial Units

DIU: Declining Industrial Units

TIU: Total Industrial Units

TJ : Total Jobs

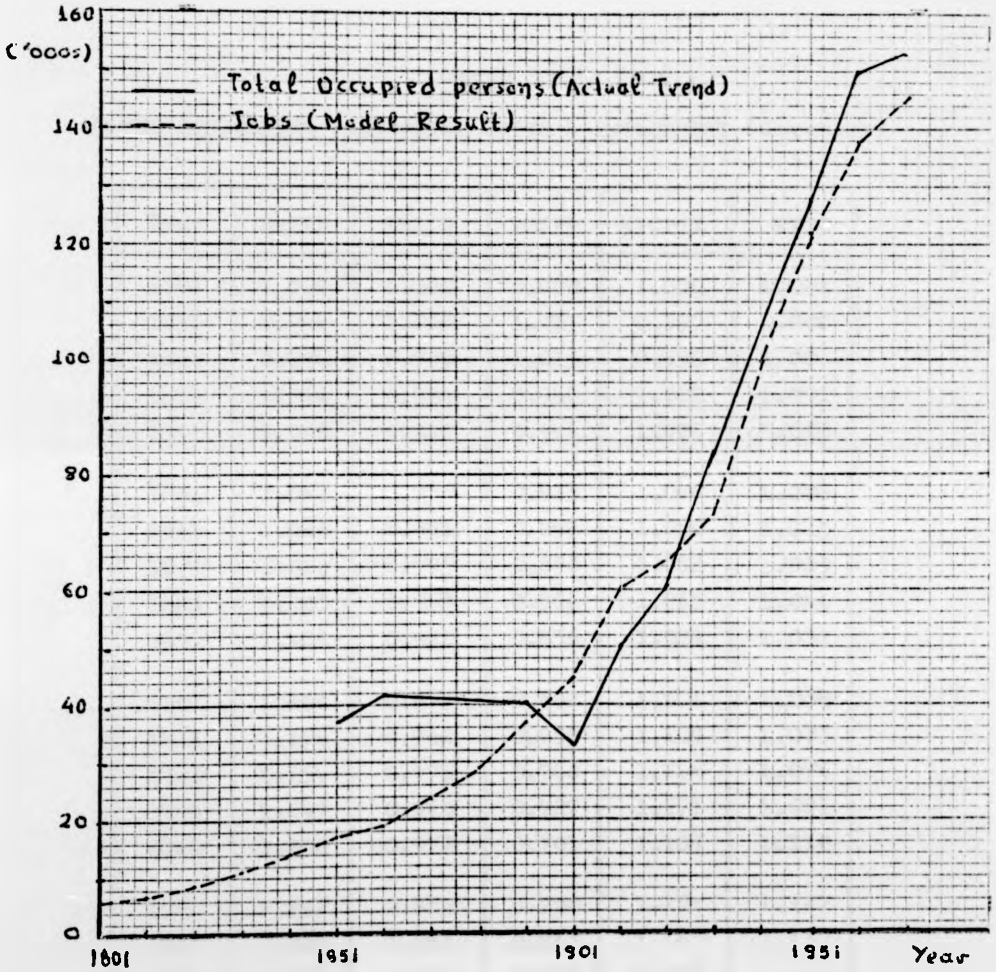

Figure 12.9 Jobs, Total Occupied persons (Coventry)

tion censuses and labour gazettes show that up to 1860 a considerable proportion of Coventry's workforce (appr. 25%) were occupied in growth industries (primarily textile industries) as compared to a national average of around 20%. The collapse of the ribbon industry was a blow for Coventry but watchmaking proved a succesful transitional solution until the establishement of the cycle and later motorcar industry. The inter-war and post-war periods saw the rapid deve-

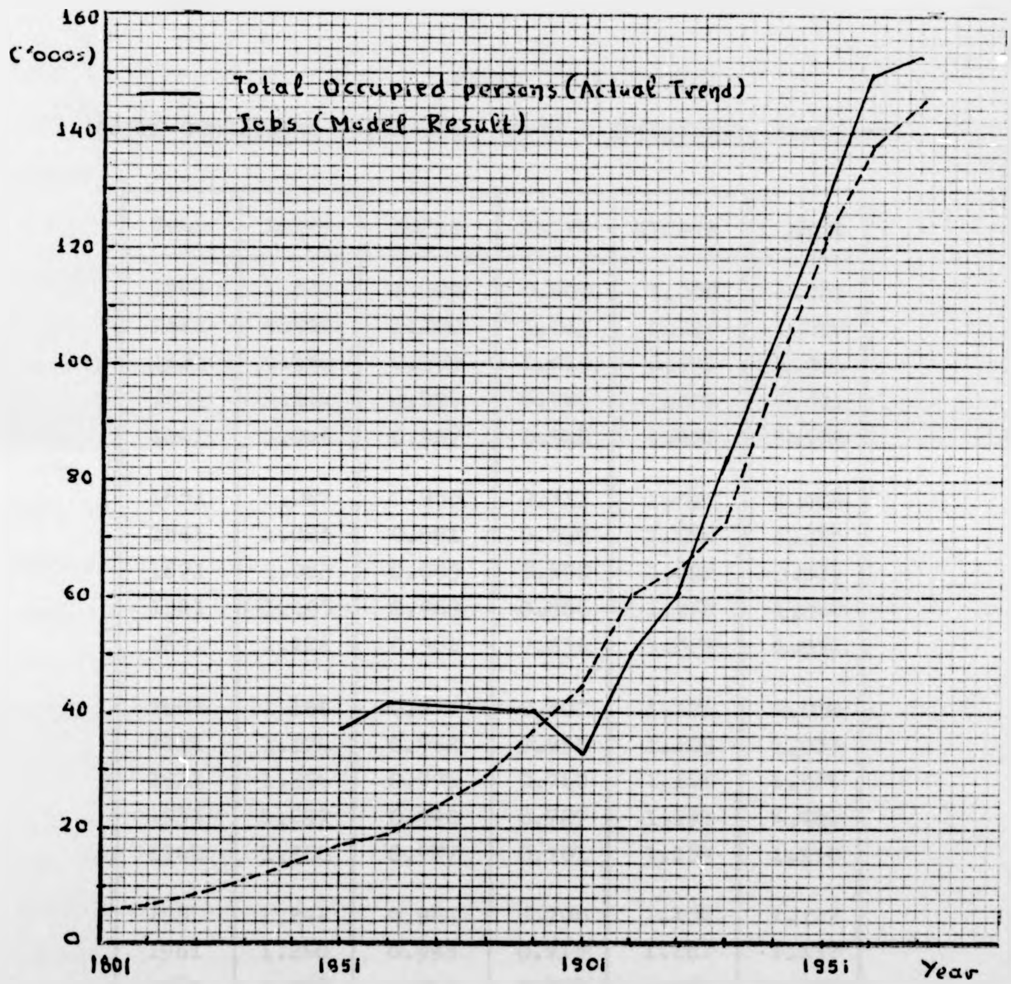

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TABLE 12.19 (M.R.)

RATES CONCERNING INDUSTRIAL UNITS & EMPLOYMENT (Coventry)

Year	RNIFR	RMIFR	RDIFR	RICPIX	RTJR
1801	1.000	1.000	0.000	1.000	1.001
1811	0.996	1.000	1.013	0.997	1.000
1821	0.994	0.999	1.013	0.996	1.001
1831	1.014	0.994	0.986	1.007	1.001
1841	1.046	0.987	0.946	1.027	1.003
1851	1.067	0.985	0.913	1.040	1.008
1861	1.083	0.991	0.899	1.050	1.015
1871	1.082	0.993	0.890	1.052	1.029
1881	1.105	0.989	0.866	1.065	1.040
1891	1.126	0.982	0.836	1.079	1.051
1901	1.166	0.977	0.802	1.101	1.059
1911	1.174	0.962	0.758	1.109	1.073
1921	1.254	0.976	0.740	1.146	1.076
1931	1.297	0.990	0.727	1.171	1.081
1941	1.250	0.977	0.701	1.159	1.110
1951	1.242	0.984	0.700	1.154	1.127
1961	1.260	0.998	0.713	1.161	1.137
1971	1.305	1.019	0.729	1.180	1.141

KEY

RNIFR : Relative New Industries Fraction

RMIFR : Relative Mature Industries Fraction

RDIFR : Relative Declining Industries Fraction

RICPIX: Relative Industrial Composition Index

RTJR : Relative Total Job Ratio

lopment of motor-car industry and Coventry was the centre of it. Between 35-40% of its workforce were occupied in related industries, as compared to a national average of about 5-10% . On the basis of the presented information the trend of the Relative Fraction of New Industries (RNIFR) as produced by the model seems to fit historical reality with the possible exception of the period 1860-1880. The reasons for this discrepency have already been discussed. Finally the proportion of New Industries for the last few years as given by the model may be slightly overestimated because Government Controls aiming to restrict the inflow of industries to rapidly growing areas have not been modelled. The last column of Table 12.19 concerns job availability. Although actual data (Table 11.14) and model output (RTJR) are not directly comparable a broad similarity of trend can be established as both indicate lower than normal unemployment rates for the period 1930-1970.

Table 12.20 contains model-output variables concerning industrial infrastructure. Its last column (RUFIBF - Relative Unfit Industrial Buildings Fraction) is indirectly comparable to available data expressing industrial dereliction. Local Government returns in1966 gave industrial dereliction for the County of Warwickshire as approximately 0.75 times the national average. For the same period the model gives the proportion of Unfit Industrial Buildings for the city of Coventry as 0.82 times that of the normal city.

Residential Activity

Table 12.21 gives the number of housing units of every type as obtained by the model. Figure 12.10 compares the trend of the housing stock level as obtaindd by the model with that given by the relevant official statistics. As in the case of Oldham the model's

TABLE 12.20 (M.R.)

LEVELS & RATES CONCERNING INDUSTRIAL BUILDINGS (Coventry)

Year	FIB	UFIB	RUFIBF
1801	673	0	0.000
1811	797	11	1,002
1821	953	49	1.008
1831	1,170	110	1.002
1841	1,413	187	0.977
1851	1,748	279	0.946
1861	1,987	390	0.920
1871	2,444	524	0.898
1881	2,935	682	0.876
1891	3,671	865	0.847
1901	4,389	1,080	0.815
1911	6,070	1,152	0.789
1921	6,552	1,252	0.783
1931	7,327	1,419	0.770
1941	9,923	1,472	0.760
1951	12,266	1,499	0.772
1961	13,907	1,444	0.801
1971	14,476	1,451	0.826

KEY

FIB : Fit Industrial Buildings

UFIB : Unfit Industrial Buildings

RUFIBF: Relative Unfit Industrial Buildings Fraction

TABLE 12.21 (M.R.)

LEVELS CONCERNING HOUSING UNITS (Coventry)

Year	HCHU	MCHU	LCHU	FHU	UFHU	THU
1801	218	1,165	1,555	2,938	0	2,938
1811	255	1,363	1,679	3,297	193	3,490
1821	309	1,643	1,924	3,876	410	4,286
1831	389	2,047	2,318	4,754	654	5,408
1841	475	2,478	2,685	5,638	932	6,570
1851	584	3,009	3,166	6,759	1,254	8,013
1861	667	3,304	3,499	7,470	1,682	9,152
1871	814	4,019	4,135	8,868	2,192	11,060
1881	1,012	5,103	5,164	11,309	2,729	14,038
1891	1,343	6,508	6,432	14,283	3,328	17,611
1901	1,639	7,839	7,391	16,869	4,042	20,911
1911	2,161	10,194	9,406	21,761	4,705	26,466
1921	2,496	10,984	10,837	24,317	5,990	30,307
1931	3,411	14,574	14,188	32,173	7,603	39,776
1941	4,923	19,292	18,466	42,681	9,206	51,887
1951	6,743	23,329	24,611	54,683	10,393	65,076
1961	8,862	28,507	32,449	69,818	11,001	80,819
1971	9,161	30,009	37,665	76,835	12,199	89,034

KEY

HCHU: High-Cost Housing Units

MCHU: Medium-Cost Housing Units

LCHU: Low-Cost Housing Units

FHU : Fit Housing Units

UFHU: Unfit Housing Units

THU : Total Housing Units

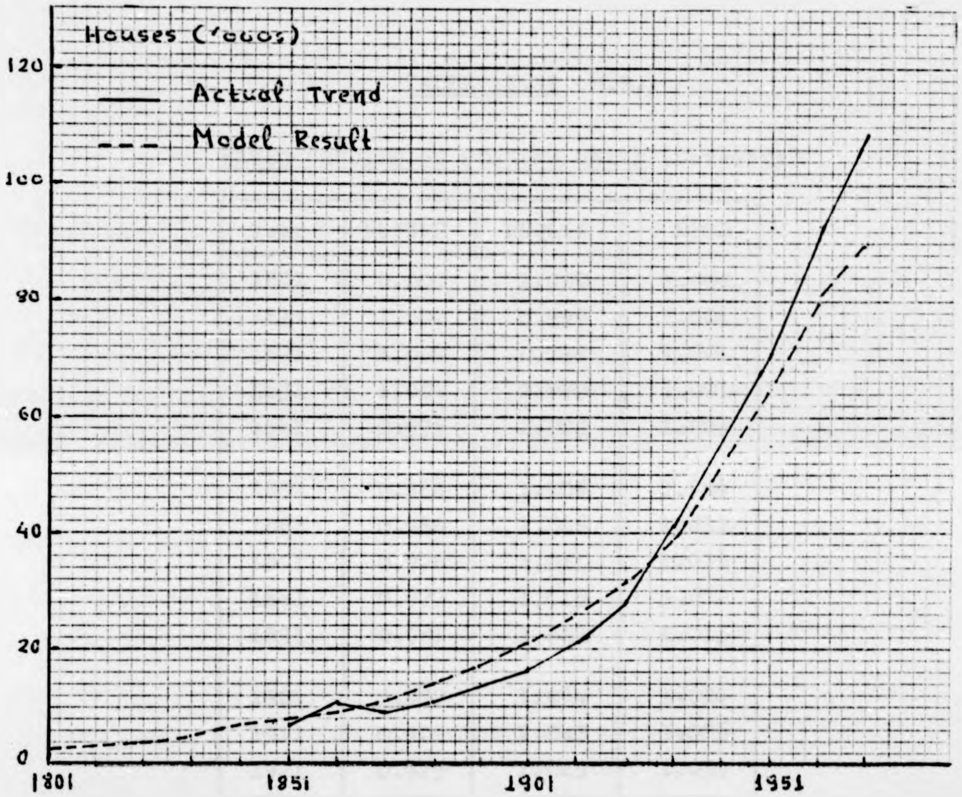

Figure 12.10 Houses (Coventry)

output follows closely the actual trend.

Table 12.22 contains information concerning the quality and availability of Coventry's housing stock as compared to that of the normal city. As we have seen in the previous chapter official statistics give the proportion of unfit houses in Coventry in 1966 as 0.8 times the national average. For the same period the model gives a proportion (RUFHFR) 0.90 times that of the normal city. The last column of Table 12.22 gives the ratio of families over the availble housing units. The nearest available data is the number of persons per room as given by the census for the period 1911-1971 (Table 11.16). The si-

TABLE 12.22 (M.R.)

RATES CONCERNING HOUSING UNITS (Coventry)

Year	RUFHFR	RHQLIX	RFHR
1801	0.000	1.000	1.000
1811	1.002	0.999	1.001
1821	1.009	0.998	1.001
1831	1.004	0.999	1.001
1841	0.995	1.002	1.003
1851	0.984	1.006	1.004
1861	0.986	1.006	1.012
1871	0.976	1.011	1.013
1881	0.977	1.015	1.012
1891	0.951	1.024	1.013
1901	0.927	1.034	1.024
1911	0.909	1.042	1.026
1921	0.975	1.023	1.059
1931	0.998	1.025	1.037
1941	1.023	1.026	1.017
1951	0.989	1.031	1.022
1961	0.931	1.041	1.024
1971	0.903	1.048	1.036

KEY

RUFHFR: Relative Unfit Housing Fraction

RHQLIX: Relative Housing Quality Index

RFHR : Relative Fit Housing Ratio

milarity in trend betwemn the actual data and the model results is clearly shown.

12.4 CONCLUSIONS

Chapter 12 was devoted to the testing of the descriptive power of the proposed model. Coventry and Oldham were used as test--beds and in both cases the trends of certain key variables, as obtained through the model, displayed a close fit to the respective actual trends. Those two cities have followed quite distinct paths of development over the period covered by the model. Furthermore they may be considered as representatives of two large families of cities including the major industrial cities of this country. Therefore it would be fair to claim that the satisfactory results obtained by the model for those 2 cities is a strong positive indication of its descriptive power.

12.5 ADDITIONAL RUNS

Once the model had been proved successful in generating the development of Oldham and Coventryadditional runs for other cities were performed. Population was the only output produced in those cases. The following figures illustrate graphically the population trends as given by the census. Hypothetical trends which would have been obtained if the cities had developed under normal conditions are also shown. In cases of significant boundary extensions a second graph is also drawn. It compares the population trend as obtained through the model with a hypothetical trend of the city's population which would have been obtained if no boundary extensions had taken place. In all cases the performance of the model has been proved satisfactory.

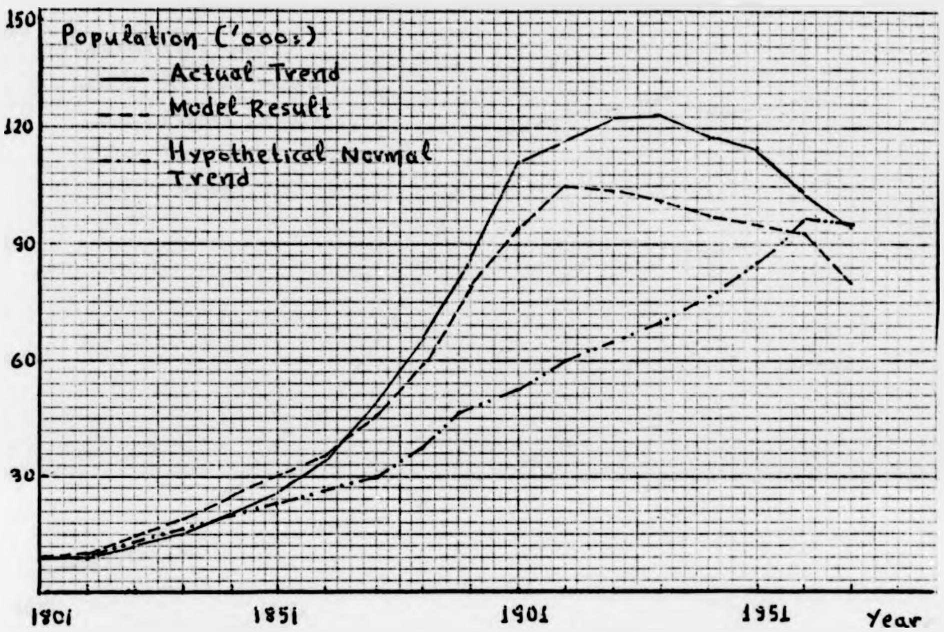

Figure 12.11 Population(Gateshead)

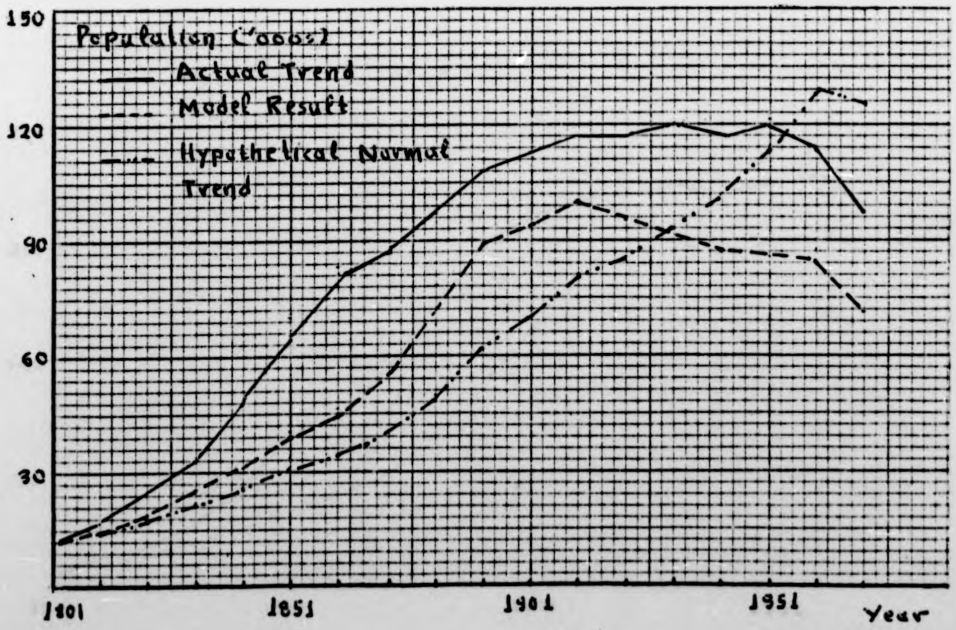

Figure 12.12 Population (Preston)

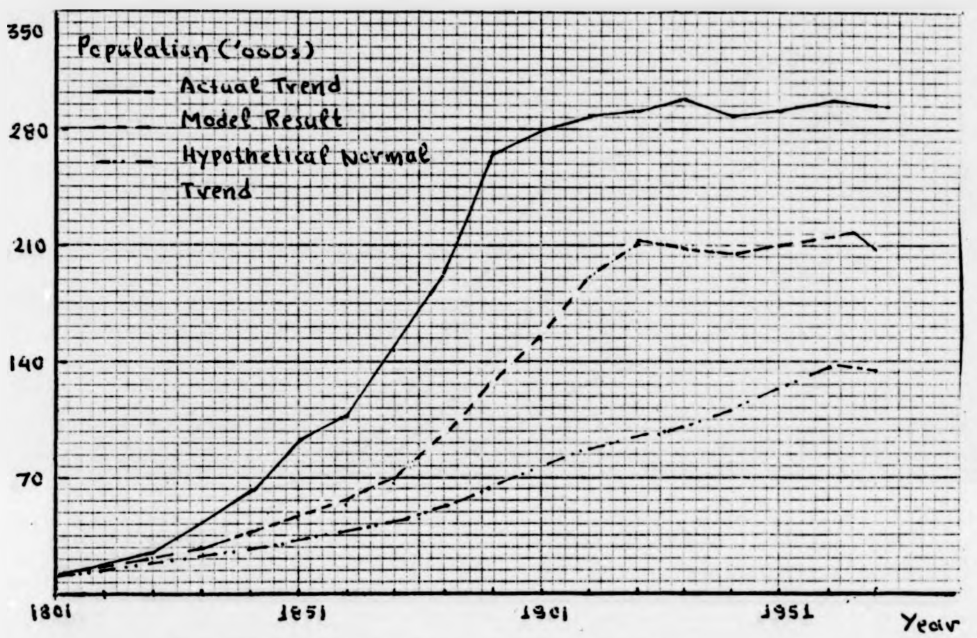

Figure 12.13 Population (Bradford)

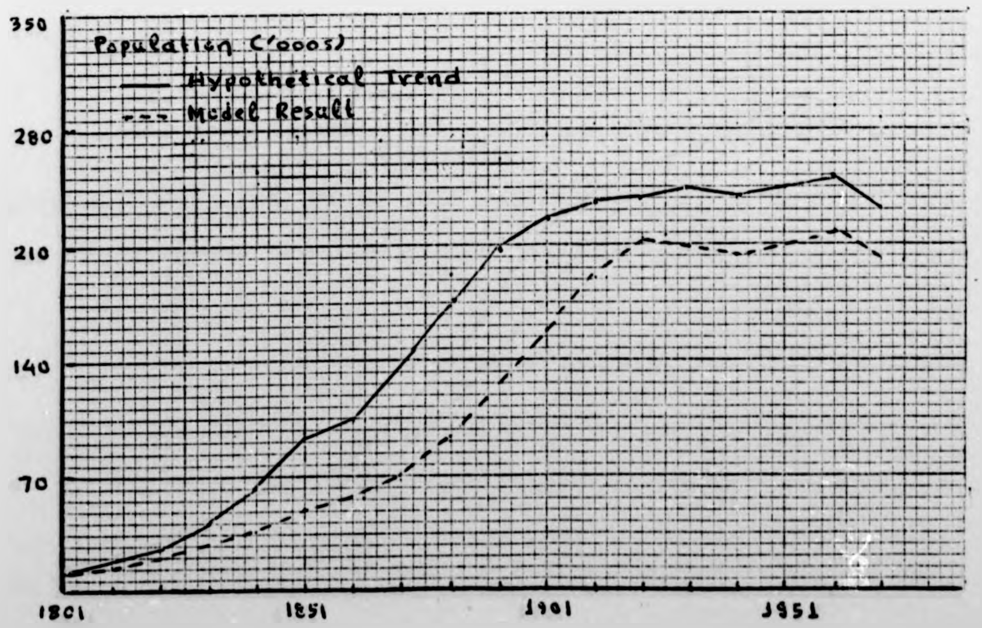

Figure 12.14 Population (Bradford) when boundary changes are taken into account.

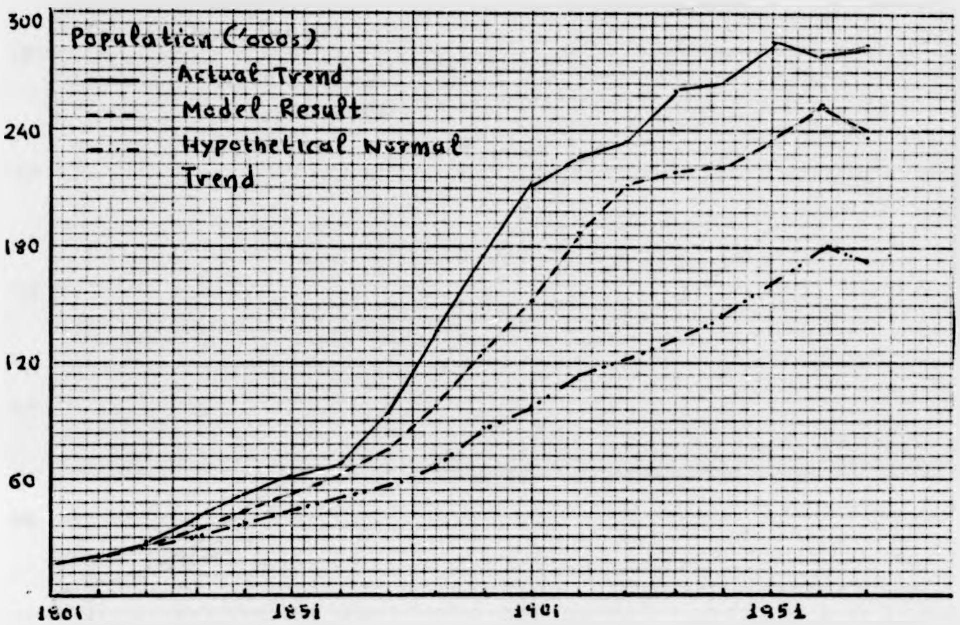

Figure 12.15 Population (Leicester)

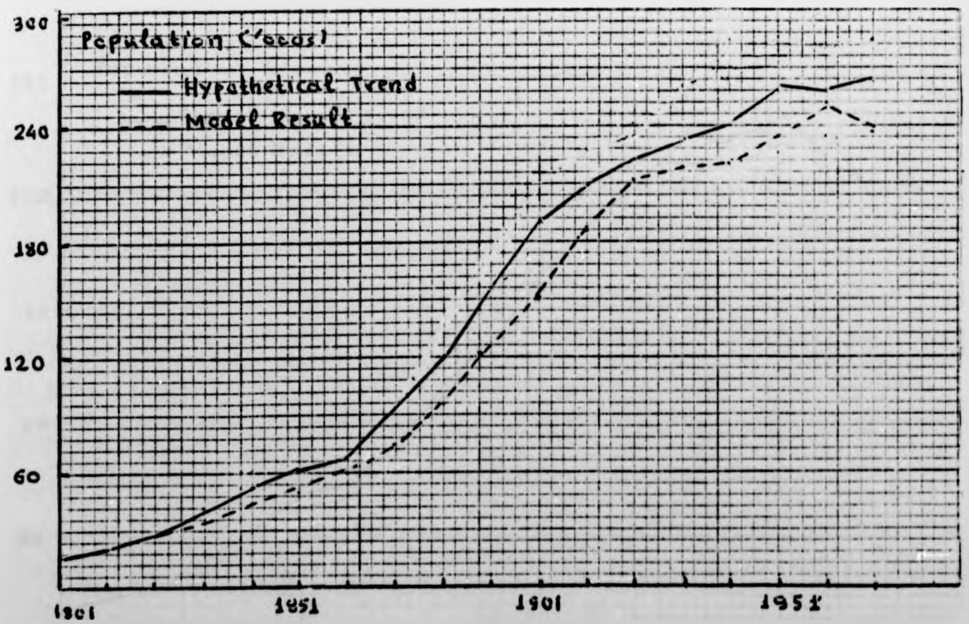

Figure 12.16 Population (Leicester) when boundary changes are taken into account

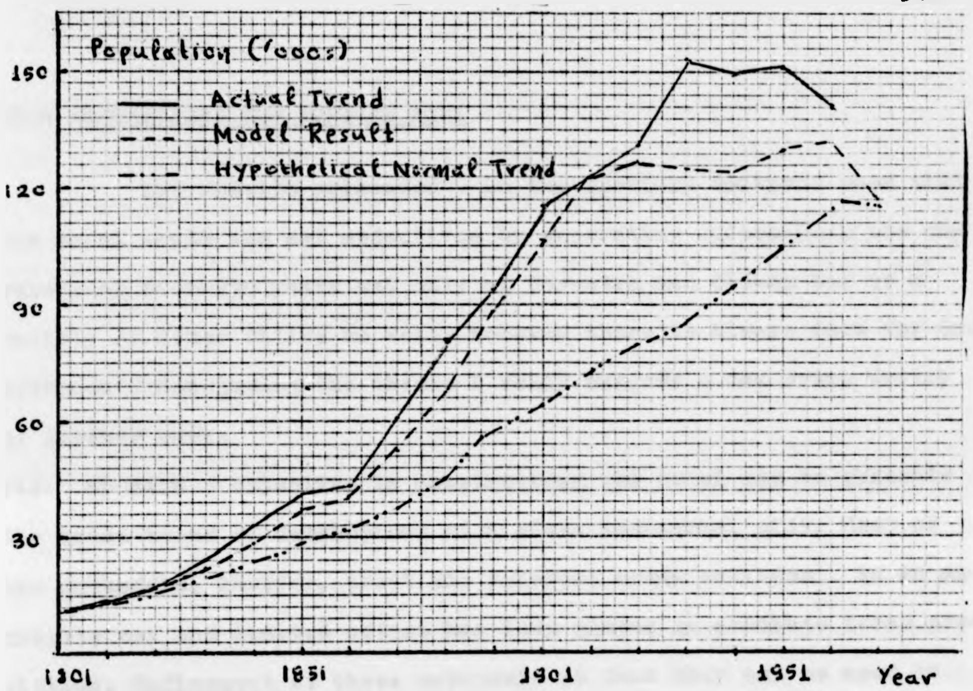

Figure 12.17 Population (Derby)

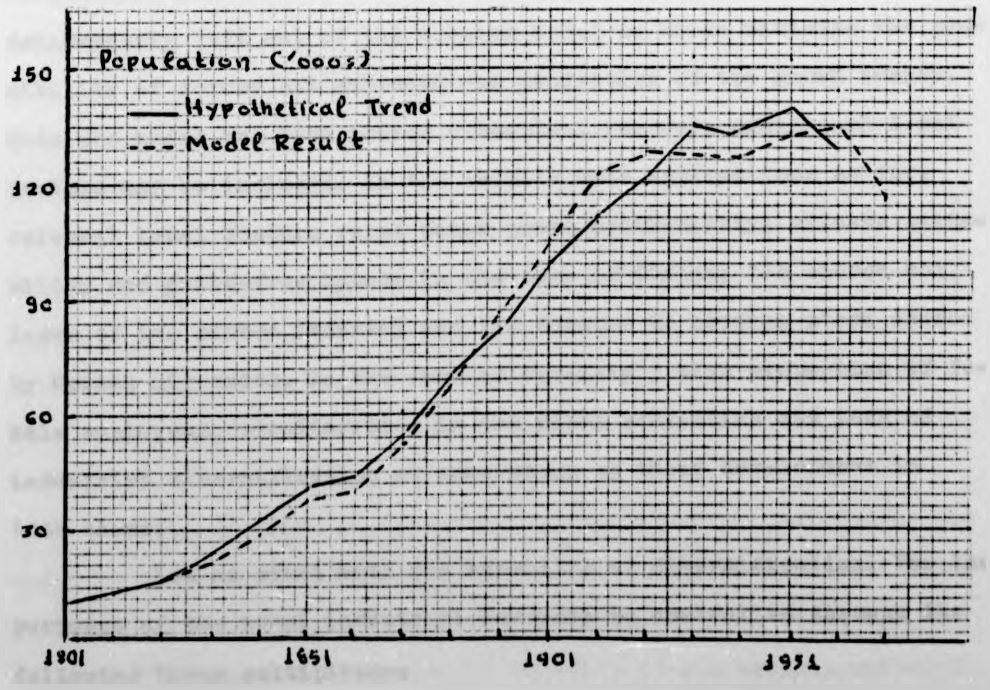

Figure 13.18 Population (Derby) when boundary changes are taken into account

12.6 SUGGESTIONS FOR FURTHER WORK

The results presented in the previous sections show that the model meets the set objectives by generating successfully the development over 170 years not only of Coventry and Oldham but of a variety of other cities as well. However there is always room for improvement. Concluding the thesis I shall suggest a few areas worthy of further work.

(i) My main objective in constructing the model was to generate the broad trend of development of a given industrial city. Most of the submodels, however, treat the relevant urban entities in an aggregate way and limited effort has been placed on absolute terms prediction. Refinement of those submodels so that they can be used in their own right is a potential field of further work.

(ii) Many relevant local factors of secondary importance as well as certain external factors which are difficult to quantify have been deliberately left out of the working model so as to minimise the possibility of forced but subconscious projection of the known trends. Once the model has been proved effective, however, additional local factors may be included. In the model's main applications so far, relevant local factors were: water power availability, climate suitability and guild-free labour in the case of Oldham; the sudden collapse of the ribbon industry and the damages to housing stock caused by German air-raids, in the case of Coventry ; high proportion of female employees, peculiarities in the vital statistics and lack of industrial diversification at some stage of their development in both cases.

Let me start with the modelling of diversification. For the purposes of the model industrial movement is controlled through the following three multipliers:

NIAM (New Industries Attraction Multiplier) (eq. 3004)

MIAM (Mature Industries Attraction Multiplier) (eq. 3006)

MIDPM(Mature Industries Departure Multiplier) (eq. 3202)

The aspect of diversification may be introduced if we multiply each one of those by a relevant factor i.e.

(NIAM)(1/DIVF)

(MIAM)(1/DIVF)

(MIDPM)(1/DIVF)

where DIVF (Diversification Factor) expresses the degree of diversification for the given city. DIVF = 1 indicates normal diversification while its value decreases with increasing dependence on a particular industry. By means of this modification the model will generate faster industrial growth for a city dependent on a single prospering industry (i.e. Oldham 1800-1880, Coventry 1900-1960) than the growth of an equally attractive city with a mixed industrial basis. Similarly it will generate faster decline for a city based on a single declining industry (i.e. Oldham 1890-1940). Multipliers controlling the construction and vacation of industrial buildings (IBCNM,IBVCM) may be also modified accordingly.

Peculiarities in vital statistics may be modelled by modifying the relevant rates. The higher proportion of female employees may be taken into account by increasing the number of economically active non-heads per family (NHEAPF). Similarly the labour-intensiveness of a certain industry may be generated by increasing the number of jobs per industrial unit (JPIUN).

The collapse of the ribbon industry may be included in the model by introducing exogenously the sudden death of a defined number of industrial units. Similarly damages to housing stock may be generated by a sudden "transfer of a number of fit housing units of every type to the unfit group.

The availability of guild-free labour may be included in the model by modifying the Labour Availability Multiplier (LBAVM) or the Perceived Specific Imafe for.New Industries (PSPINI). Finally, the presence of water resources — or indeed the presence of any natural resources— and the suitability of climate may be modelled by modifying the Relative Accessibility Index((RACSIX). The effect of additional natural resources and other relevant physical advantages were tested for the cases of Oldham and Preston. In both cases RACSIX was increased by about 15% for the period 1800-1860 and the model rerun under the new conditions. The obtained population trends (Figures (12.19,12.20) show a considerable improvement in fit to historical reality. Careful modelling of all relevant secondary local factors will undoubtedly improve the performance of the model and such an exercise is suggested as another area of further work.

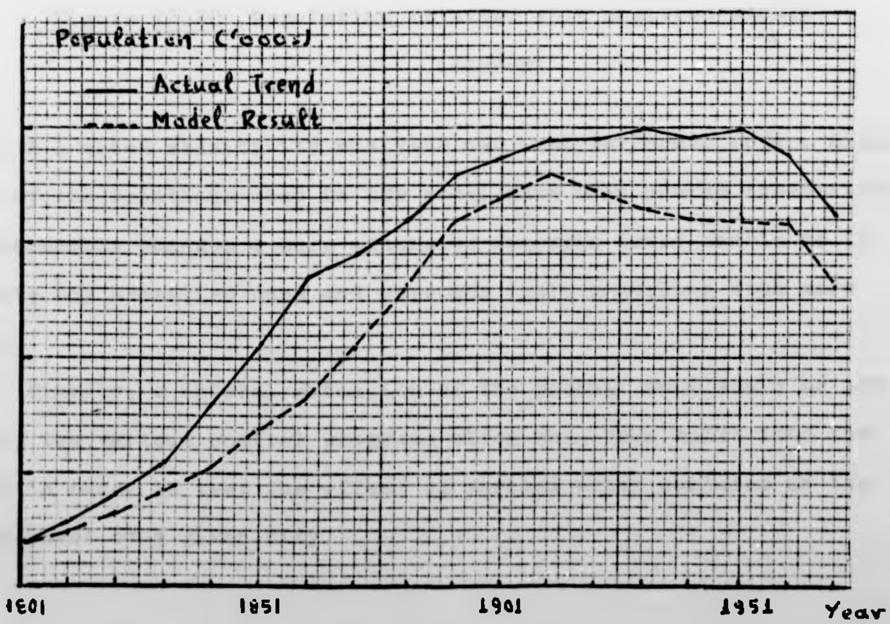

Figure 12.19 Population obtained with modified RACSIX (Preston)

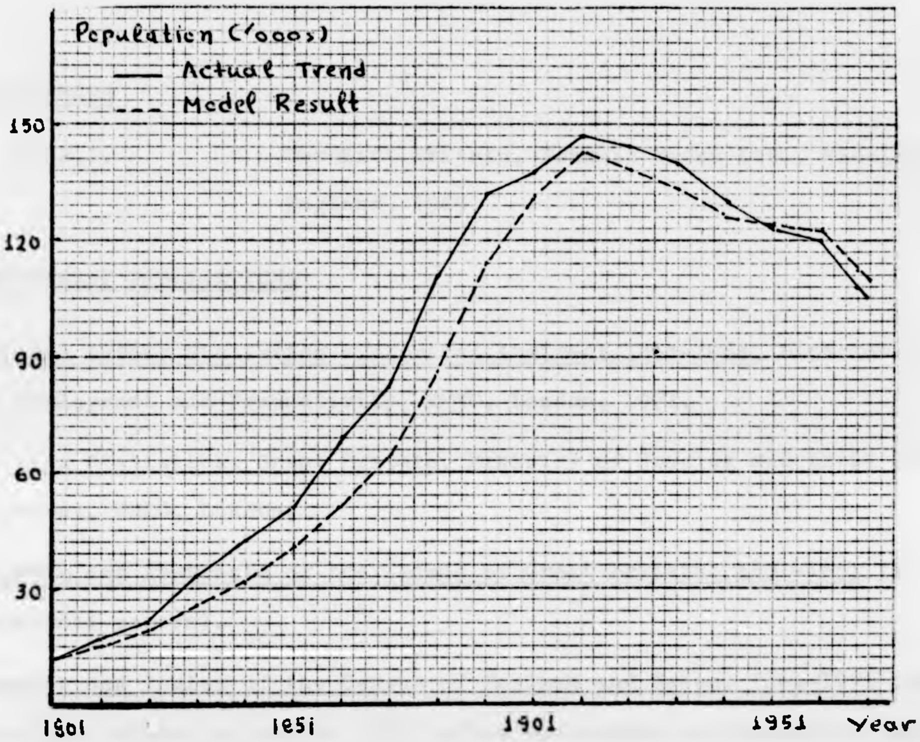

Figure 12.20 Population obtained with modified RACSIX (Oldham)

(iii) A limited sensitivity analysis has been performed sofar. Although most of the relations used in the model have been proved insensitive to reasonable changes a more extensive analysis would enable us to isolate any sensitive ones and approach their modelling with more care.

(iv) Finally, a natural extension of the present work would be the use of the various control programs which have been built into the model in order to test the effect of various urban policies on the development of a given city.

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Epilogue

Eulpides and Pisthetaerus, heroes of the play "Birds" written by Aristophanes at around 400 B.C., search for the ideal city. They reach the conclusion that no such city exists and with the help of the birds they build a new city in the sky which they call Cuckoonebulopolis. Their happiness however, is short-lived. Several malefactors and public nuisances who had been plaguing life on earth for many years, soon move into the new city to exploit a virgin field; also, a delegation of angry gods arrive to protest about the city blocking the sacrifices ascending from the earth. More than two thousand years later, the search for the ideal city has not become any easier and the idea of a modern Cuckoonebulopolis is still very much alive.

Aristotle had defined the city as the place for "good living" but there is no indication of this in J.P. Sartre's perception of the contemporary city. "You take a piece of bare sterile land and you roll some big hollow stones on to it. Inside those stones smells are held captive, smells which are heavier than air. Now and then you throw out of the window into the streets and they stay there until the winds tear them away. In bright weather, noises come in at one end of the town and go out at the other, after going through the walls; at other times they go round and round between thse stones which are baked by the sun and split by the frost". Obviously this is a literary and emotional description of a city but nevertheless an ever increasing number of city dwellers become dissatisfied and disillusioned. Cries like "our cities are rotting" or "the end of the city" have become commonplace and the future looks uncertain. The problems facing the modern city, however, are not insoluble; what is required is a clear understanding of their nature and the coordination of the various groups involved in city affairs towards their solution. I hope that the present work will prove a useful tool in this process. Cities must be improved for our own sake and it must be remembered that escape in the sky is not always the best answer to earthly problems.

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